A Case Study of the Effects of Enclosure Elements on Energy Consumption in a High-rise Office Building

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ABSTRACT

A Case Study of the Effects of
Enclosure Elements on Energy Consumption
in a high-rise office building

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This report presents a case study of the effects of certain building envelope parameters on the annual energy requirements of a high-rise office building.

The major objective of this study is to evaluate the impact of wall insulation thickness, and the quality of the fenestration on the building energy requirements, so that the planning team can assess the economical feasibility of these various alternatives in the early stages of designing an energy efficient building.

The energy requirements estimates for various composite wall constructions were obtained by using a Commercial Program as made available by Public Works Canada.

The results of the analysis of eleven different composite wall assemblies are tabulated and indicate graphically the variation of energy use that follows increasing thickness of wall insulation and changes in fenestration.

Acknowledgements

The writer would like to acknowledge the direction of the Center for Building Studies who made the budget available for the computer time necessary for this analysis, as well as, the guidance, comments and criticism of Prof. Mal Turaga and other members of the faculty and staff of the Center for Building Studies of Concordia University.

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LIST OF SYMBOLS

Af	floor area (SQ-Ft)
Ag	glazed area (SQ-Ft)
Ar	roof area (SQ-Ft)
Aw	area of curtain wall (SQ-Ft)
BTU	British thermal unit
CFM	cubic foot per minute
Cp	specific heat of air (Btu/lbs. DEG-F)
CD	clear double - glazing
CT	clear triple - glazing
ERE	energy requirement estimate
°F	degree fahrenheit
ho	BTU/(hr. Ft^2 °F)
HVAC	heating, ventilation and air conditioning
kW	kilowatt
MBH	thousand Btu per hour
MPH	miles per hour
RD	reflective double - glazing
S	density of air (lbs/CU-Ft)
SC	shading coefficient of glass (dimensionless)
SHGF	solar heat gain factor (Btu/hr . SQ-Ft)
toa	outdoor air temperature (DEG-F)
tr	room temperature (DEG-F)
ts	supply air temperature (DEG-F)
TD	tinted double - glazing (solar bronze)
Ug	U-value of glazing (Btu / hr . SQ-Ft . DEG-F)
Ur	U-value of roof (Btu/HR . SQ-Ft .DEG-F)
Uw	U-value of curtain wall (Btu/hr . SQ-Ft . DEG-F)
VAV	variable air volume system

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CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

In 1980, an opportunity was presented at the Center for Building Studies to perform an energy analysis for a major office building, that was in the early stages of construction. The HVAC system designs for the building were completed, but there was still time to make modifications to the thickness of the insulation in the curtain walls or to alter the type of fenestration, if these changes could be economically justified.

The study was therefore, to examine the impact of changes in the various components of the vertical building envelope on annual energy requirements.

The effects of eleven combinations of curtain wall insulation and glazing types, on the annual energy consumption, using a commercially available energy requirement estimate program, were analyzed in this study.

The results of the analysis i.e. the variation of the annual heating, cooling and total energy requirement changes in the enclosure elements were analyzed.

Details of the energy requirement estimation program were presented in Chapter 3.

1.1 Enclosure element variations considered in the analysis

The existing building envelop or skin, has a metal curtain wall, with 4" compressed glass fiber insulation, in the non glazed areas. The glazed areas are double glazed with sealed units, with solar bronze outer, and, clear inner panes. The details of the variation were shown in Tables 1, 2 and 3.

1.2 The major findings of the study can be summarized as follows:

1- As expected, the heating requirements for the building constituted a major portion of the total annual energy requirements, due to the climatic conditions for this location; consequently, for a given glazing percentage, the wall insulation thickness is the most significant parameter in determining the total energy requirement.

2- Among the glazing types considered, as expected, the clear triple glazing (highest thermal resistance) with 6" - wall insulation (highest thermal resistance) provided the least total

TABLE 1 - GLAZING AND WALL INSULATION VARIATIONS

CONSIDERED IN THE ANALYSIS

VARIATION NO.	SYMBOL	GLAZING TYPE	GLASS FIBER WALL INSULATION THICKNESS	
1	TD	Solar bronze double	4"	Base case
2	TD	Solar bronze double	2"	
3	TD	Solar bronze double	6"	
4	CD	Double clear	4"	
5	CT	Triple clear	4"	
6	CD	Double clear	2"	
7	CT	Triple clear	2"	
8	CT	Triple clear	6"	
9	RD	Reflective film double	4"	
10	RD	Reflective film double	6"	
11	CD	Double clear	6"	

TABLE 2 - AVERAGE COEFFICIENT "U" SUMMER & WINTER FOR COMPOSITE WALL

RUN	Wall Insul.	Glazing	Average Coefficient "U" Wall Coeff X "U"	%	Area	Winter Glass Coeff. "U"	%	Area	Summer Glass Coeff. "U"	%	Area	Overall Average Coefficient 'U' Winter	Summer	RUN
1	4"	T.D.	.06	.42	.029	.43	.52	.224	.45	.52	.234	.253	.263	1
2	2"	T.D.	.114	"	.055	.43	"	.224	.45	"	.234	.279	.289	2
3	6"	T.D.	.04	"	.019	.43	"	.224	.45	"	.234	.243	.253	3
4	4"	C.D.	.06	"	.029	.49	"	.255	.56	"	.291	.284	.320	4
5	4"	C.T.	.06	"	.029	.31	"	.161	.39	"	.203	.190	.232	5
6	2"	C.D.	.114	"	.055	.49	"	.255	.56	"	.291	.310	.346	6
7	2"	C.D.	.114	"	.055	.31	"	.161	.39	"	.203	.216	.258	7
8	6"	C.T.	.04	"	.019	.31	"	.161	.39	"	.203	.180	.222	8
9	4"	R.D.	.06	"	.029	.43	"	.224	.37	"	.192	.253	.221	9
10	6"	R.D.	.04	"	.019	.43	"	.224	.37	"	.192	.243	.211	10
11	6"	C.D.	.04	"	.019	.49	"	.255	.56	"	.291	.274	.310	11

T.D. = Tinted double glazing - solar bronze
C.D. = Clear double glazing
C.T. = Clear triple glazing
R.D. = Reflective double glazing
R.T. = Reflective triple glazing

U : coefficient expressed in Btu / (hour) (square ft.) difference in temperature between the air on the two sides.

TABLE 3

VALUES OF COEFFICIENT "U"

	SC *	U (Winter)	U (Summer)
Double Clear Glazing 2 x ¼" X ½" Airspace	0.88	0.49	0.56
Triple Clear Glazing	0.71	0.31	0.39
Solar Bronze Outside Clear Inside Double Glazing	0.58	0.43	0.45
Double Clear Glazing with bronze film on inside of outer pane	0.38	0.43	0.37
2" Fiberglass Wall Insulation		0.114	
4" "		0.06	
6" "		0.04	

* SC Shading Coefficient

energy, which is the alternative for the least heating requirement. However the least cooling energy requirement was provided by the alternative N°9 (reflective double glazing with 4" wall insulation), due to the solar heat reflection characteristics of the glazing. Consequently, one can conclude that, for cases where the cooling loads is predominant, the reflective double glazing may be the better choice.

3- Based on the discounted pay back period analysis, for this project, none of the enclosure elements considered are economical, at the energy costs considered, which also indicates that the original design of the building (base case - alternative N°1) is energy effective.

CHAPTER 2
DESCRIPTION OF THE BUILDING AND THE MECHANICAL SYSTEM

2.0 BUILDING AND MECHANICAL SYSTEM DESCRIPTION

2.1 General description of the building

The building analyzed is a 29 story office building situated in Western Canada and is part of a larger complex comprising a podium 3 stories high, i.e. basement, first and second floors, commercial areas and an adjacent parking garage. The analysis is limited to the 25 office floors only.

2.2 Building zoning

The typical floor plan is shown in Figure 1, with the sub-divisions of the floor area into North, South, East, West and Core Zones, again for purposes of energy requirement estimation.

The core area covers the rentable area in the interior zone but does not include elevator area, wash rooms, duct shafts, staircases as indicated.

This core area, as such, has no outside walls, hence no envelope losses or gains.

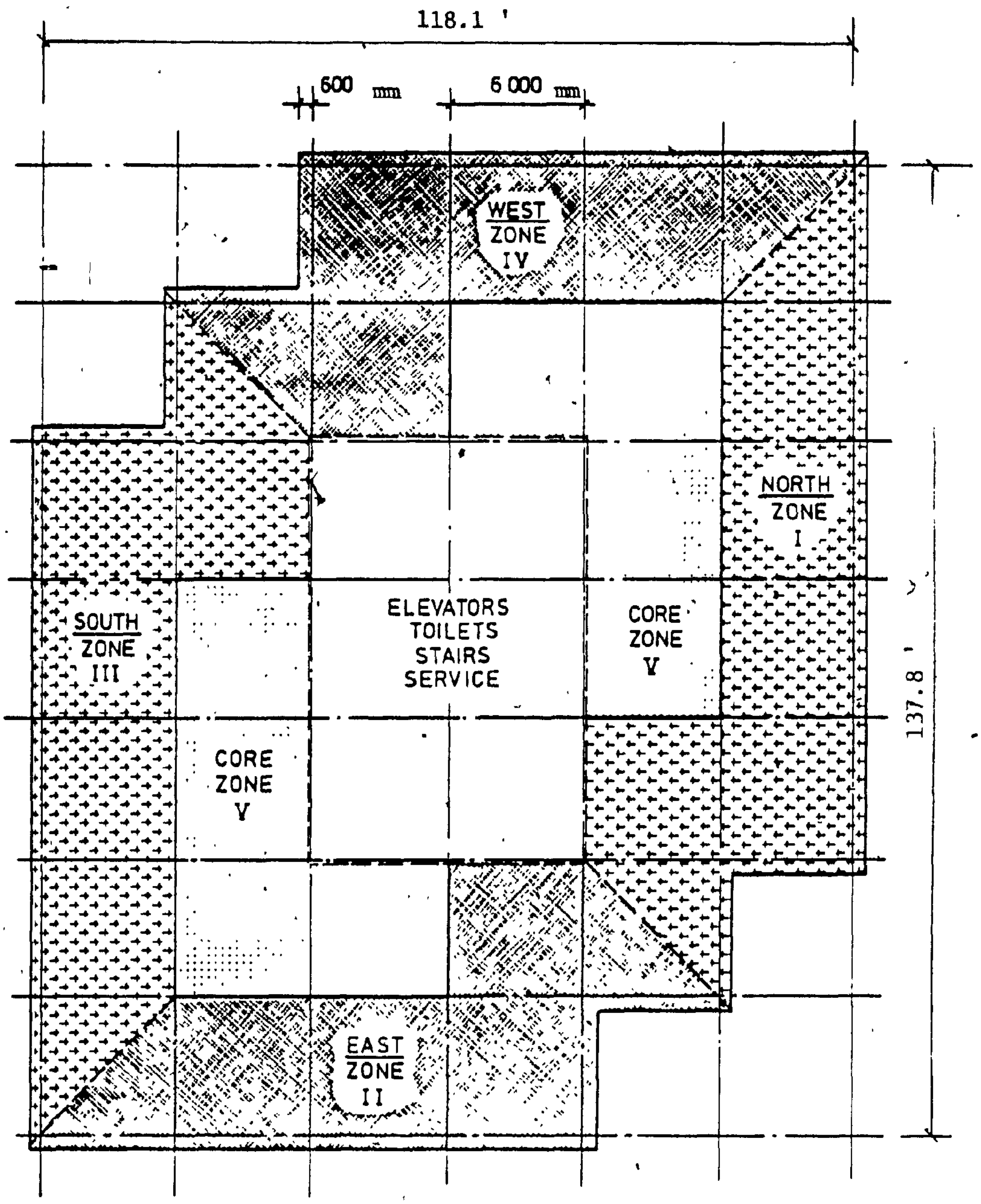

FIG. 1 FLOOR PLAN (TYPICAL FLOOR) SHOWING ZONES USED FOR COMPUTER ANALYSIS

The building skin or vertical envelope is a metal curtain wall with 4 inches of compressed glass fiber insulation in the non-glazed area. The glazed area consists of double glazed sealed units with bronze solar glass outside and clear glass inside.

The perimeter areas are conventionally one bay or 15 to 20 feet wide to account for the effects of outdoor weather conditions and solar radiation.

A typical section through the wall is shown in Figure 2 and the summary of the major building specifications were shown in Table 4.

The cooling and ventilation is by means of a VAV (variable air volume) system with sprayed coil cooling (1) and economizer cycle as shown in attached Figure 3. Secondary heating is by means of a hot water heated baseboard radiation located on the perimeter of the outer zones. The perimeter heating is controlled by an indoor-outdoor scheduled temperature controller.

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(1) The supply air is cooled by a coil through which chilled water is circulated. The exterior of the coil is sprayed with water to wash the air, humidify the air and obtain additional evaporative cooling.

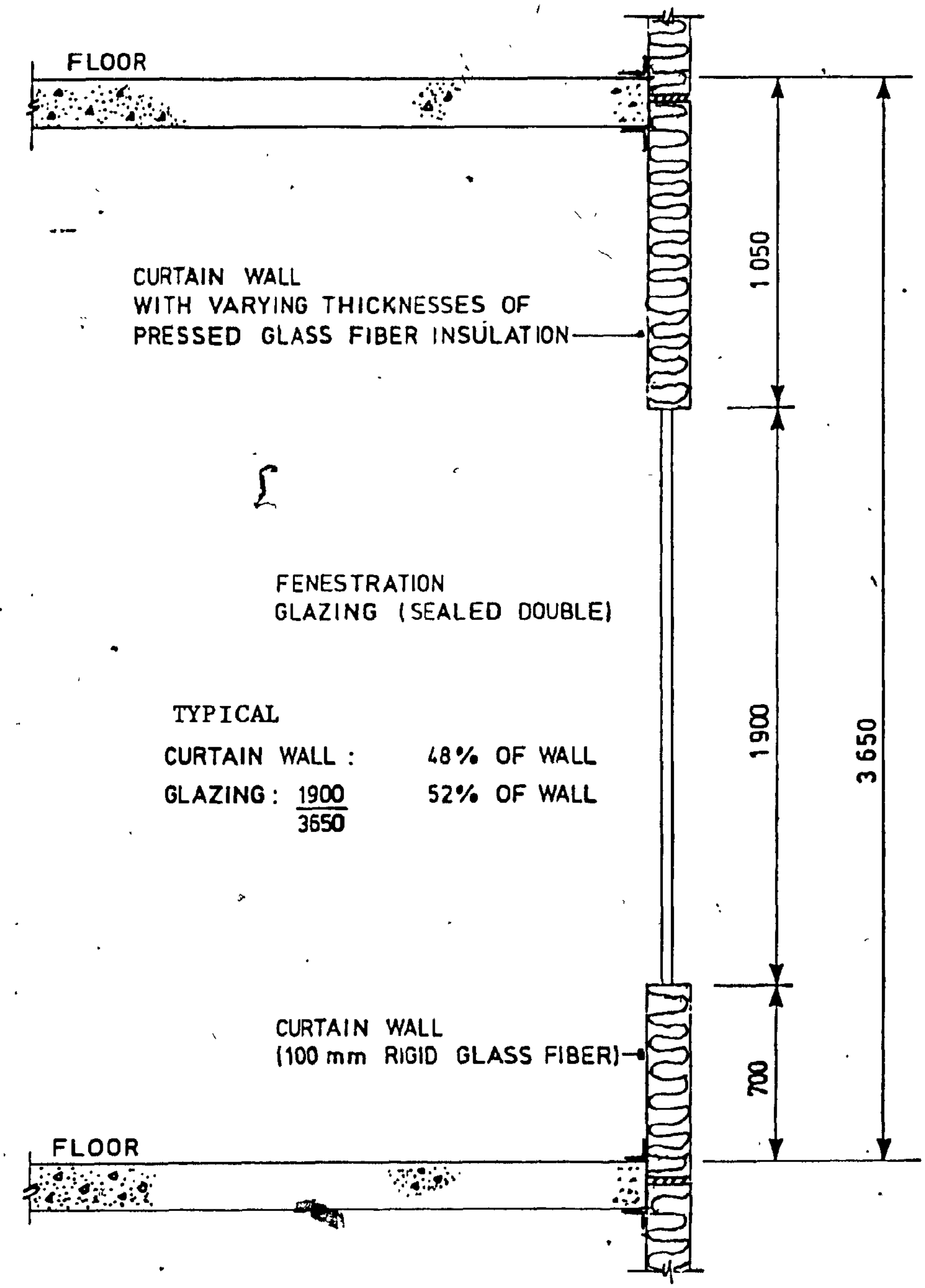


FIG.2

TYPICAL WALL SECTION

DIMENSIONS ARE SHOWN IN mm.

(Not to scale)

TABLE 4

SUMMARY OF MAJOR SPECIFICATIONS

No. of office floors 25

Total rentable area 322,787 sq. ft. (30,000 m^2)

Typical floor to floor height 11.975 ft. (3.65 m)

Glazing .52 % of wall area

Lighting & appliances 3.15 W/sq.ft. (33.9 w/m^2)

HVAC SYSTEM

Total chiller capacity 1302 tons (4578 kW)

Chiller I 44% of total

Chiller II 56% of total

(electrical driven centrifugal chillers)

NO. of boilers 4 (gas fired)

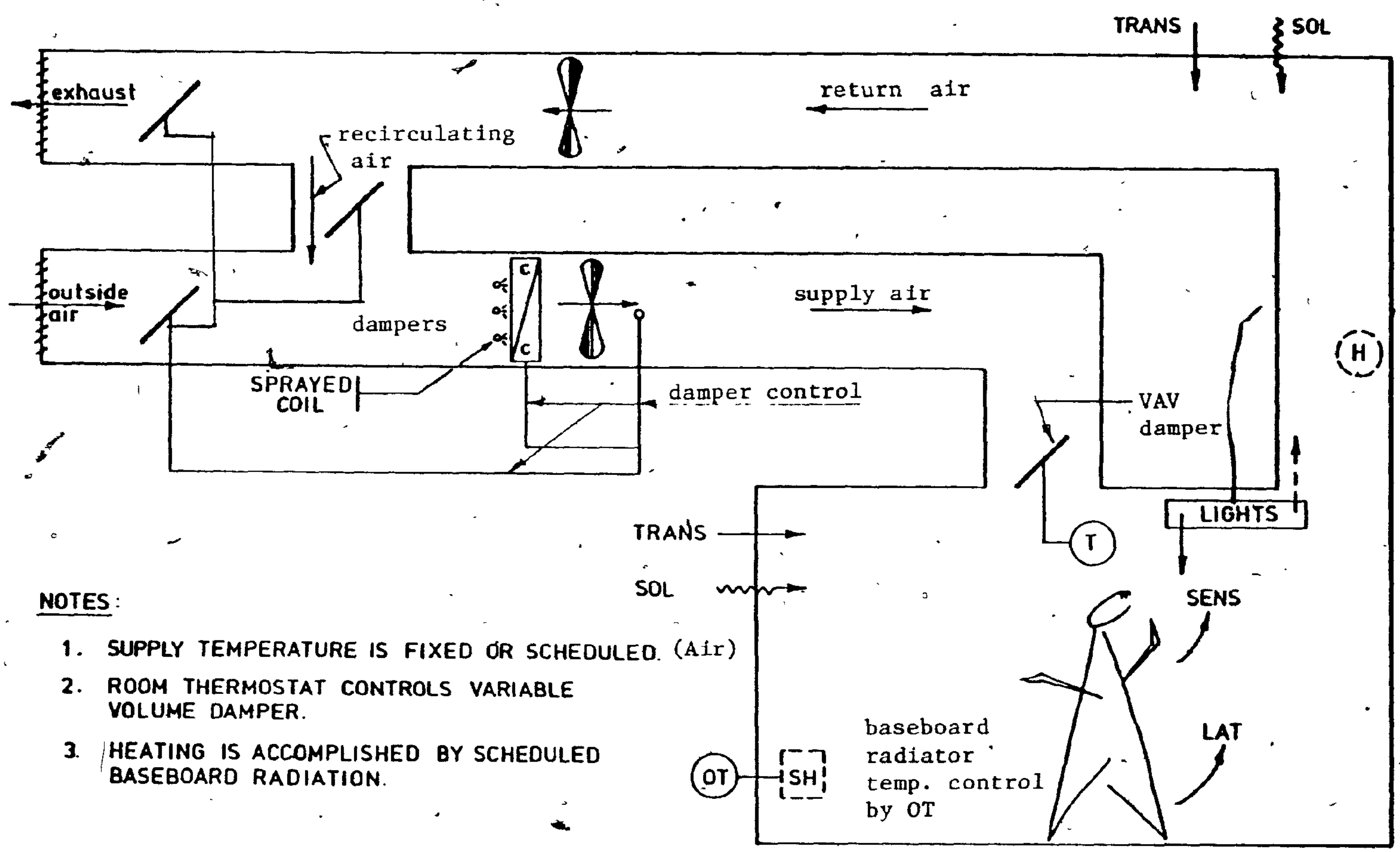
Total capacity 24,000 MBH (5624 kW)

Total air volume flow 392,946 CFM (185,450 l/s)

Lighting intensity & type 3 w/ sq. ft. fluorescent

Base case maximum heating or cooling CFM / Ft^2 : 1.65

H Humidistat
T Room Thermostat
OT outdoor temperature sensing stat



NOTES:

1. SUPPLY TEMPERATURE IS FIXED OR SCHEDULED. (Air)
2. ROOM THERMOSTAT CONTROLS VARIABLE VOLUME DAMPER.
3. HEATING IS ACCOMPLISHED BY SCHEDULED BASEBOARD RADIATION.

FIG. 3 Variable air volume air conditioning system schematic

The VAV diffusers are controlled by thermostats in the core zone with volume varying from 40 to 100% of design. In the perimeter zones, the VAV (variable air volume) diffusers are used to control the air volume variation. The thermostat controlling the variable air volume also controls the perimeter baseboard radiation in sequence when required.

There are 2 mechanical rooms, the lower on the 3rd floor and the upper on the 29th floor.

Supply and return fans, cooling and spray coils are located at each of these mechanical rooms.

The two electrically driven centrifugal water chillers having a total capacity of 4 578 kW (1302 tons) of refrigerating effect, one for 44% and the other for 56% of the total load, are located in the upper mechanical room. The cooling towers and the 4 gas fired boilers each with a capacity of 1 406 kW (6000 MBH) output, are also located in the upper mechanical room.

Electrical substations and motor control centers are also located in each of these mechanical rooms.

Service water is heated electrically at each floor in the service core adjacent to the wash-rooms.

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2.3 Control system, and sequence of operation

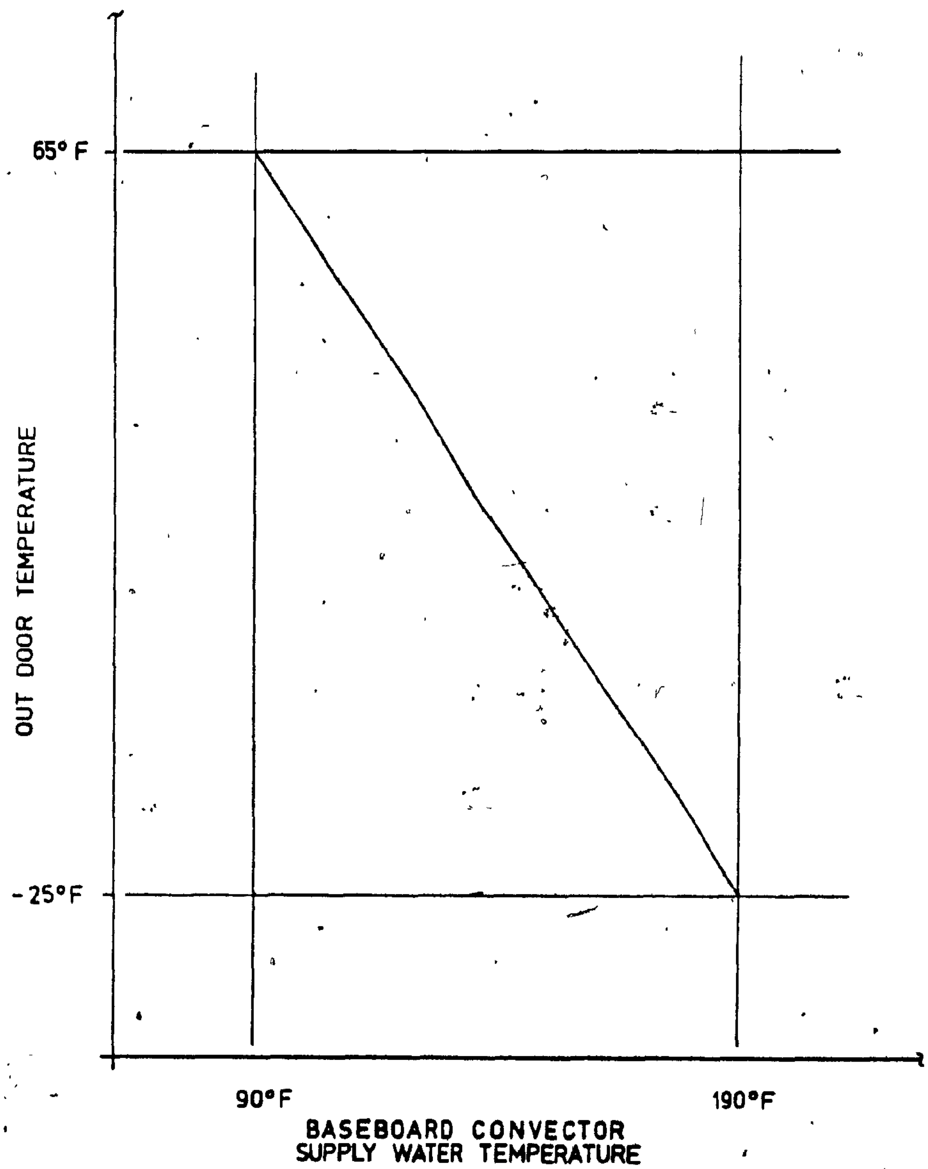
a) The cooling coils with chillers and cooling towers come into operation when outside air temperature is above 10°C (50°F.) - Below 10°C (50°F.), outside air is mixed with return air to obtain "free cooling".

b) The supply fan is a draw through type, i.e. the supply air is cooled and then drawn through the supply fan. As the fan and motor are in the air stream, the air picks up the heat from the motor horsepower input and the supply air is reheated by from 2 to 5°F, depending on the mechanical heat available from the fan electrical motors.

c) The space thermostats control the linear VAV (variable air volume) supply diffusers, and the perimeter heating baseboard radiation in sequence. When the building is unoccupied, the air system can be shut off to conserve energy. In winter, the perimeter baseboard heating compensates for skin transmission losses. The heating water temperature is controlled by an indoor-outdoor temperature control. (see Figure 4).

FIG.4

OUT DOOR/IN DOOR CONTROL.
WATER TEMP SCHEDULE
DESIGN ROOM TEMP. = 68°F (20° C)
(Hot water heating)



d) Air static pressure controllers are located in the supply and return air ducts, at various levels, to signal to the supply and return air fans, to vary the volume of air circulated as a function of the variation in air quantities demanded by the zones. (see Figure 5). The air demand will vary with variations in the solar load, skin transmission losses or gains, internal load, (people, lights, etc).

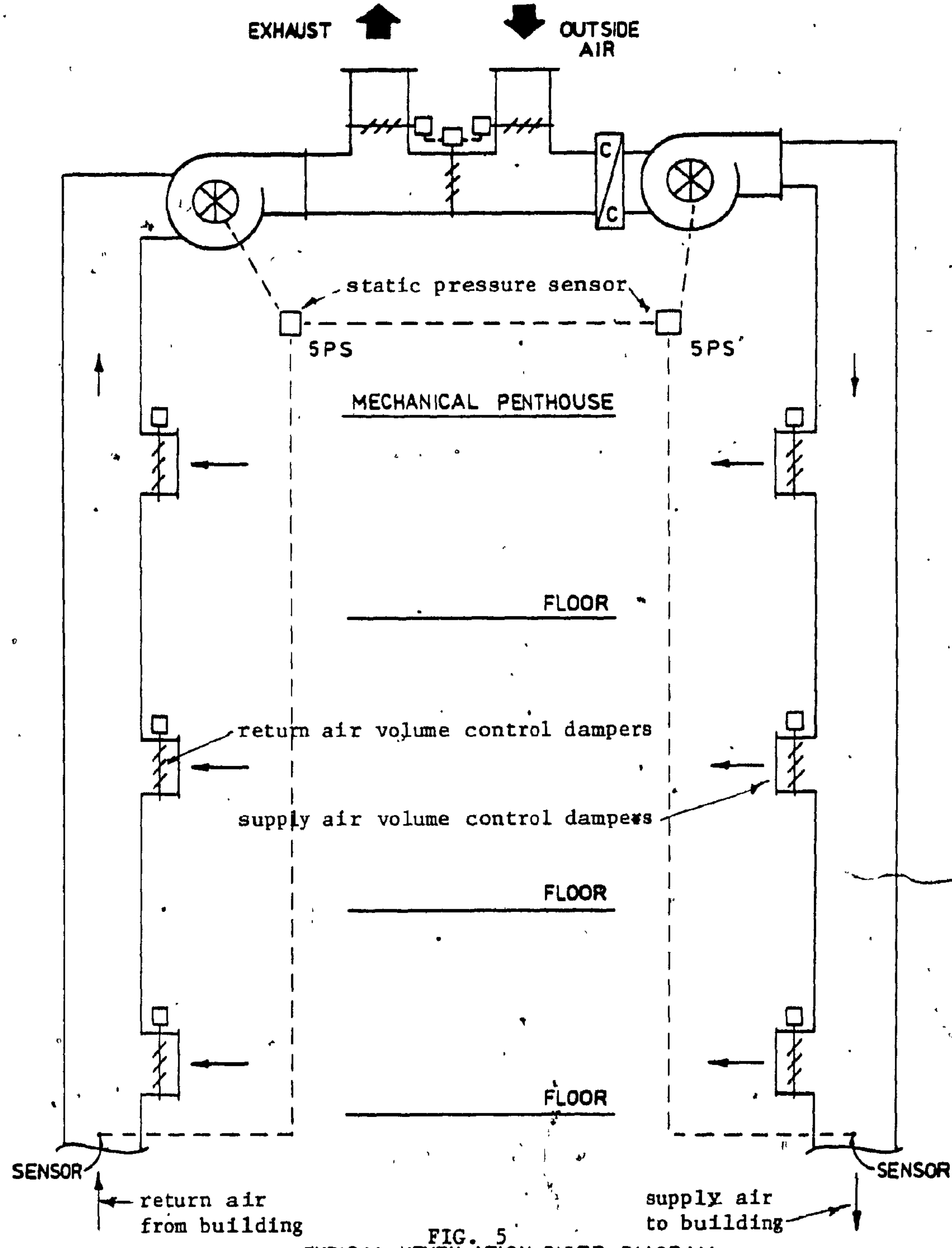


FIG. 5
TYPICAL VENTILATION RISER DIAGRAM
INDICATING STATIC PRESSURE CONTROLLERS

CHAPTER 3
DESCRIPTION OF THE ENERGY REQUIREMENT ESTIMATION PROGRAM

3.0 PUBLIC WORKS CANADA AND THE ESA

(Energy Systems Analysis)

In 1971 Public Works Canada instituted a program to identify methods whereby the energy consumption of public buildings could be reduced. During this study, it was demonstrated that computer simulation is the most realistic and useful tool for the analysis of energy consumption in buildings. Owing to the complexity of both building structures and HVAC systems, and to the large variability in space loads from people, lights, transmission, solar, and equipment, computer simulation is indispensible to predict the energy requirements of the space and of the system servicing that space.

The potential for energy and cost savings via building energy analysis is very significant. The National Energy Board has predicted that before 1980 the energy consumption in commercial buildings alone will exceed 1.5×10^{15} BTU annually at a cost of some $\$3 \times 10^{9}$ based on \$2. per 10^{6} BTU. Numerous examples of building energy analysis with the ESA Series and other programs both in Canada and the U.S.A. have shown that 10% - 20% energy waste may not be an unrealistic figure. Thus in Canada, savings on the order of $0.5 billion annually are possible via the minimization of energy waste from commercial buildings alone.

3.1 Application of ESA (Energy Systems Analysis programs) in Design

The Energy System Analysis Series is a library of computer programs developed by Ross F. Meriwether and Associates, Inc. for hour-by-hour calculation of the annual energy consumption in buildings including the simulation of various types of air-side systems and mechanical plants; for applying local utility rate schedules to these demands and consumptions; and for combining these costs with other owning and operating costs for year-by-year cashflow projections. Each major step in the complete energy system analysis is handled by a different program, thereby permitting the Engineer to evaluate the results of one part before finalizing inputs and proceeding with the next part. As a design tool, the programs permit the Engineer to predict the effects on energy performance of: different air-side system types, various control temperatures, airflow quantities, operation schedules, heat recovery or economizer cycles, various equipment types and accessory combinations. The impact on owning and operating costs by competing energy sources, alternate utility rates, and a variety of economic factors, may be determined.

An important distinction exists between design point load programs and energy consumption programs. The Energy System Analysis Series (ESA) is designed to calculate monthly and annual energy requirements and costs, not design point heating and cooling loads. These programs begin with design point loads for the overall building, or major building sections, and distribute them throughout a full year cycle of the building's operation. If the Engineer is already using a load program, it is usually a simple matter to use a summation of the zone load components from that program as input for the building energy requirements program. The ESA programs are intended to supplement rather than replace existing load programs or calculation techniques. The programs offer the consulting Engineer an excellent means to evaluate his design and to modify it according to improvements learned by noting how energy requirements for his system respond to varying load and weather conditions.

Weather data is, of course, necessary for an energy analysis. Hourly weather data that is used in the energy requirements calculations is obtained from Environment Canada and consists of 8,760 hourly values of dry bulb temperature, dew point temperature, and cloud cover for some typical year. Programs have been developed for selecting and preparing this weather data for use in the Energy

Systems Analysis Series. Since the weather data is usually selected and ordered only once for a given city, Public Works Canada would normally process the weather data on behalf of the user. If a project is located in a city for which suitable weather data already exists, the user can access the data without delay. Solar radiation tables, as published in the ASHRAE Handbook of Fundamentals, are available with the weather data which is supplied to the users. One may, alternatively, create one's own solar heat gain factors with the aid of the Solar Table Generating Program as outlined below.

3.2 The ESA programs

The Energy System Analysis (ESA) series contains the following six programs:

- Energy Requirements Estimate (ERE)
- Total Coincident Requirement (TCR)
- Equipment Energy Consumption (EEC)
- Monthly Utility Costs (MUC)
- Economic Comparison of Systems (ECS)
- Solar Table Generating Program (SL2)

Figure A shows the typical flow of information via these programs in the process of performing an energy analysis. A brief resumé of each program is given below. Complete descriptions of each program, including input/output reference instructions, are contained in subsequent chapters.

Energy Requirements Estimate (ERE) Program - calculates hourly thermal and electrical loads for the space under consideration. These loads are used in simulating the hour-by-hour operation of the air-side system in maintaining the desired space conditions. This simulation provides the hourly and annual building energy requirements. Typically a building is partitioned into "thermal blocks", or thermodynamically uniform zones, and one ERE simulation, or run, is performed for each thermal block. This block may be unique relative to other blocks in the building, or it may be one typical of many, such as a single unit in an apartment building.

Total Coincident Requirement (TCR) Program - sums the results from the ERE program for the individual thermal blocks so that a complete picture of the hour-by-hour thermal and electrical energy requirements is presented. In addition, total loads with actual diversity are indicated. As shown in Figure A, the ERE outputs are stored on tape in preparation for input to the TCR program.

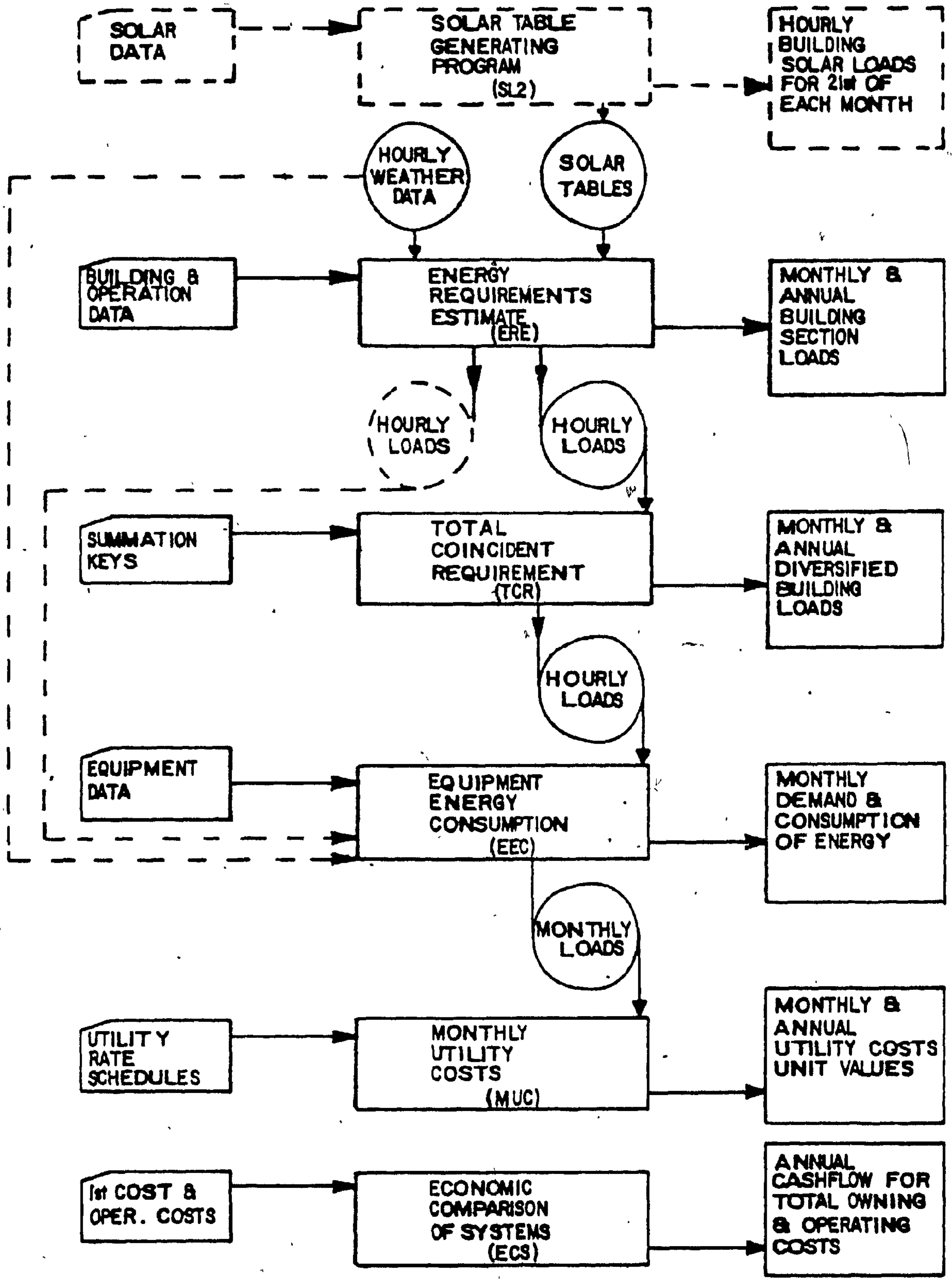


FIG. A

THE ENERGY SYSTEM ANALYSIS SERIES

Equipment Energy Consumption (EEC) Program - utilizes the output data from the ERE or TCR programs in combination with the capacity and part load performance of each piece of equipment supplying energy to the air-side system. The program determines the monthly and annual energy peaks and consumption for energy input to various systems and accessories being evaluated.

Monthly Utility Costs (MUC) Program - calculates the monthly and annual energy costs for each type of service (gas, electric, steam or hot water, etc.). This calculation utilizes the results from the EEC program and the local utility rate schedules.

Economic Comparison of Systems (ECS) Program - uses the energy costs determined in MUC plus other operating costs, such as maintenance and operating labor, and combines these costs with initial investment and associated owning cost factors such as taxes, insurance, and depreciation, to find the annual cashflow each year for up to thirty years.

Solar Table Generating Program (SL2) - allows the user to generate his own solar heat gain tables for use as input to the ERE program. Items which are considered include location, ground reflectivity, facting directions (to within one degree), glass characteristics, and lagging.

In this analysis, the ERE program only was utilized.

CHAPTER 4
INPUT DATA USED IN ANALYSIS

4.0 INPUT DATA USED IN THE ANALYSIS

4.1 To carry out this case study on the effects of enclosure elements on the energy requirements of a high-rise office building, the following data and/or assumptions were used in preparing the input cards:

4.1.1 Lighting level 3 watts per sq. ft. of floor area.

4.1.2 Electrical input for electrical appliances 0.15 watt/sq. ft.

4.1.3 Net leasable office space for 25 typical floors

- North thermal block or zone:	64,906 sq. ft.
- South thermal block or zone:	64,906 sq. ft.
- East thermal block or zone:	54,250 sq. ft.
- West thermal block or zone:	54,250 sq. ft.
- Core thermal block or zone:	84,475 sq. ft.
TOTAL:	322,787 sq. ft.

4.1.4 Total perimeter envelope or (wall + window) area:

ZONE	NORTH	SOUTH	EAST	WEST	TOTAL (sq. ft.)
North	37,128	------	6,483	------	43,611
South	------	37,128	------	6,483	43,611
East	6,482	------	31,234	------	37,716
West	------	6,482	------	31,234	37,716
TOTAL SKIN:					162,654

These areas with 48% insulated curtain wall and 52% glazing were used for heat loss and heat gain calculations.

4.1.5 The reference year weather data is the "typical" year, taken as an average over many years with all anomalies or unusual occurences corrected or smoothed out.

4.1.6 The weather data used for the dynamic analysis was the Canadian Government weather tape for Edmonton for a typical year.

Solar gains are actual ASHRAE solar gains on an hourly basis for a typical year with all necessary corrections incorporated.

Holiday schedule - it was assumed that the building would not be occupied on week-ends and holidays i.e. New Year's, Good Friday, Easter Sunday, Memorial Day, Canada Day, Bank Holiday, Labor Day, Thanksgiving, Christmas.

4.1.7 Weeks-ends and holidays operation

- Lighting level was assumed at 5% over 24 hours or 0.15 watts per sq. Ft.

- HVAC schedule 0-24 hours fans and cooling off, heat on perimeter on an outdoor-indoor control, heat off at 65°F. outside temperature and above.

- HVAC systems are completely shut off.

- Perimeter heating comes into operation to maintain minimum unoccupied indoor temperature of 18°C (65°F.) controlled by an outdoor-indoor temperature control.

4.1.8 Light schedule:

1) week days

	0 - 7 AM	5% of 3W/sq.ft.: 0.15W
	7 - 8	10%
	8 - 9	20%
	9 - 12	90%
(2 PM)	12 - 14	80%
	14 - 17	90%
	17 - 19	70%
	19 - 20	60%
	20 - 21	40%
	21- 22	30%
	22 - 24	5%

2) Week ends and holidays:

0 - 24 5% (0.15 watt/sq.ft.)

4.1.9 Fan system operation following building occupancy:

.1- week days start 8 AM

stop 5 PM - unless reset

.2 week ends and holidays:

0-24 hours off unless reset

4.1.10 Shading coefficient (Table 3.17 - Ref.1)

.1 Solar bronze heat aborbing; sealed unit with clear glass inside, no interior shading SC: 0.58

.2 Triple clear glass, sealed unit no interior shading SC: 0.71

.3 Double clear glass, sealed unit No. interior shading SC: 0.88

.4 Double clear glass, sealed unit with bronze reflective film on inside of outer pane SC: 0.38 (no inside shading)

4.1.11 The computer program has shading of wall capability, but no shadows or shading by adjacent buildings have been calculated as no data was given.

Shading of walls as sun rotates around the building is found in hour by hour calculations and by total ton-hour calculations, this item is included in the ERE.

Chillers are shut down:

.1 when building is unoccupied, i.e.

- between 5 PM and 8 AM week days
- Saturdays, Sundays and holidays

.2 when outside air is below 50°F.

Economizer cycle and enthalpy control are provided for in the ERE program.

The Enthalpy control will operate as long as outdoor air conditions permit free cooling or use of the economizer cycle, then the chiller will cut in, or the chiller will cut out if outdoor conditions permit the use of the economizer cycle. This will operate even on a cool morning in spring or fall.

An altitude of 2,200 Ft. A.S.L. (Above Sea Level) for psychrometric temperature and humidity conditions are reflected in the weather tapes.

.1 Indoor temperature setpoint in summer is 78°F. ambient outdoor design 85°F, DB, 66°F. DP

.2 Indoor temperature setpoint in winter is 68°F. DP, 34°F. dewpoint to prevent condensation on the windows.

.3 Heating comes on when outdoor temperature is below 65°F. and operates on an outdoor-indoor schedule.

0% heating at 65°F. outside air
100% heating at -25°F. outside air
with a straight line relationship.

There is no specific humidification equipment in the building. It takes heat to evaporate water. There are air washers in the cooling system. Therefore, in this process, there will be some humidification as a by-product of the cooling. The heat extracted in the process must be included in the heat balance. Thus, calculation is included in the ERE program.

4.1.12 The chilled water pumps, condenser water pumps and cooling tower fans are interlocked with the chillers. These auxiliaries follow the same schedule as the chillers as discussed above.

4.1.13 Heating boilers and pumps are on an outdoor-indoor control and follow transmission loss demand when outside air temperature is below 65°F., this can happen even in Summer.

They are not shut down except when heating load is satisfied and outside temperature is above 65°F.

4.1.14 The total (kW) power of the supply and return fan systems is:

-	Total upper supply	268.4 kW
-	Total upper return	74.4 kW
-	Total lower supply	268.4 kW
-	total lower return	74.4 kW
		685.6 kW

4.1.15 Wind factors used were:

- Winter 15 mph
- Summer ho : 4 (7.5 mph)
  ho : 3 (less than 7.5 mph)

4.1.16 "U" factors for wall do not differ materially from summer to winter. Glass "U" factors will vary slightly from summer to winter and these have been taken into account in calculating the U-factor for the composite wall (see Table 1).

4.1.17 The U-factor for double clear glass with bronze reflective film on the inside of the outer pane is:

- 0.43 in winter with 15 mph wind
- 0.37 in summer with 15 mph wind
- 0.40 in summer with 5 mph wind

The major heat gain in summer is not by transmission but solar.

4.1.18 When calculating the chiller electrical input to the program, include the whole chiller train that is interlocked with it, i.e. condenser and chilled water pumps, cooling tower etc...

4.1.19 People load is taken at 180 sq. ft. of floor area/person and at 450 Btu/hr/person with 44% latent heat load and 56% sensitive heat load.

4.1.20 The program takes into account equipment power input in kW, and calculates system efficiencies within the envelope or conditioned space.

System losses due to low power factor or poor utility power regulation are not included in the program.

4.1.21 The total building infiltration is taken at 16000 cfm (see calculation, Table 5).

4.1.22 For these calculations, the normal exhaust rates would be the difference between supply and exhaust to maintain the building pressurization.

This would be 18000 cfm approximately at full load VAV - as minimum VAV is 40%, then the minimum exhaust rate would be 7200 CFM when systems are running.

The actual exhaust rate could be obtained by taking the sum of the toilet exhausts for the 25 floors. These exhaust fans should be scheduled to shut off during non-occupied periods, nights, week-ends, holidays.

4.1.23 Outside or make-up air quantities will vary:

.1 on the economizer cycle it could go as high as 100%.

.2 the ventilation air required for the people occupying the building at 15 CFM/person during the heating and cooling cycle is about 10% full load.

TABLE 5

SAMPLE CALCULATION

CURTAIN WALL INFILTRATION FOR THE ENTIRE BUILDING

(Reference: Chapter 5, ASHRAE, Cooling and Heating Load - Calculation manual).

P = Building perimeter = 512 lin. ft.

H = Building height = 300 ft.

A = Area of entire curtain wall of building = 153,280 sq. ft.

Q = CFM infiltration

K = Leakage coefficient of curtain wall (dimensionless) .66

F_d = Thermal draft factor : .87

Δt =

= Winter design temperature difference = 93 ^{o}F.

$\frac{Q}{A.K.F_d}$ = 0.18 from Figure 5.6

Q = A K F_d (Q /A K F_d)

= 153,280 X .66 X .87 X .18 = 15,842 CFM

= 16,000 CFM

REQUIRED OUTSIDE AIR

. Tower Floor Area Total = 322,787 sq. ft.

. Floor Area per occupancy = 180 sq. ft

. No occupants = $\frac{\text{Total Area}}{\text{SQ. Ft. / person}}$ =

. Outside Air Required (maximum) = Occupants X 15 CFM/occupancy

= $\frac{322,787 \text{ X } 15}{180}$ = 26,900 CFM

4.1.24 Lighting was assumed by fluorescent fixtures with HPF (high power factor) ballasts calculated with 15% to plenum. The lighting kW input is converted to thermal gain for cooling load calculation. The energy input for lights appears in lights and power calculation separately.

Energy for cooling to compensate for light input appears as a cooling cost and/or as a heating credit.

4.1.25 The program adjusts its power energy requirements for fans, chiller, etc... as a function of the VAV system's demand.

4.1.26 The ERE Meriwether program for energy requirement estimate was used.

Full explanations as to procedure and input instructions are contained in the Reference Manual for Energy Systems Analysis series of programs (Meriwether) Public Works Canada (1980) - (Ref. 2).

4.1.27 The full tabulation of the input data required for the ERE analysis of each thermal block or zone is given in Table 6.

TABLE 6

ERE ANALYSIS

INPUT DATA NEEDED

FOR EACH THERMAL BLOCK OR ZONE

Floor area

System data

- Type of air distribution system (dual-duct, terminal reheat, variable volume, etc..)
- Heating capacity
- Cooling capacity

Solar load

- Reference value
- Time of occurrence
- % distribution of glass area by facing direction

Internal loads

- Peak from people
- Peak from lights
- Peak from equipment
- Peak from miscellaneous
- 24-hour profiles for each of these loads for each type of day

Transmission loads

- Heating peak and design temperature
- Cooling peak and design temperature

Process loads

- Peak indirect (such as domestic hot water or other steam loads)
- Peak direct
- 24-hour profiles for each of these loads for each type of day

Return air loads

- Roof solar and transmission
- Heat of lights
- Return fan temp. rise
- Supply fan temp. rise

Airflow quantities

- Supply air
- Outside air

Control temperatures

- Cold air supply temp.
- Hot air supply temp.
- Reset schedules for hot and/or cold air temperatures and humidification
- Economizer cycle temperature limits

Heat recovery efficiencies for energy wheel

Time schedules for each type of day

- Outside air shutoff
- Heating system shutoff or setback
- Cooling system shutoff or setback
- Off-peak electrical service

Gas curtailment temperatures or schedules

Supplementary heating system data

- Baseboard radiation schedule (temp. and/or time)

Holiday schedule

Description of profiles and operating schedules to be used with each type of day.

4.2 Limitations of the program

4.2.1 In the enumeration of the assumptions and data used as input to the various computer runs, several limitations were at least implicit (see articles 4.1.5,13).

4.2.2 Design inputs for lighting levels are set and applied on an occupancy schedule. There is no provision to account for lesser power consumption should certain tenants have lower lighting levels as in landscaped offices with task lighting.

4.2.3 There is a great deal of flexibility in the program but it cannot be in all ways matched to existential conditions. It remains a simulation, no matter how skillfully the simulation is carried out.

4.2.4 Inherent problems with each of these programs (Meriwether ERE, Calerda, Blast, etc...) are not only making the correct input to allow the program to carry out the simulation, it is designed to do, but once this simulation is complete, for the analyst to correctly interpret the resulting print-out.

Unless the analyst has a great deal of experience in the design of building HVAC systems, as well as trouble shooting in these areas, he or she will not be able to use all the information that is made available by these simulations.

4.2.5 ERE were calculated with Summer design room temperatures of 78°F. and Winter of 68°F. should the tenants adjust thermostats locally, energy use will be affected.

4.2.6 People load was assumed at 180 sq. ft. per person. This may vary considerably.

4.2.7 Building infiltration may vary considerably as a function of the quality of the workmanship. Average figures were used in this case.

4.2.8 The building is divided into thermal blocks or zones i.e. North, South, East, West and Core.

Each of these zones are analyzed separately and are considered as if not interacting upon each other.

4.2.9 Many of the variables, ventilation rate, infiltration, lighting levels, internal heat gains (population) are held constant during fixed schedules (i.e. occupied or unoccupied periods).

4.2.10 The intent of the program is to get as close as possible to the overall building energy used without excessively detailed input.

4.2.11 Summary of the input data and output were shown in Table 6 and 7 respectively.

Sample output data were shown in Appendix "A".

TABLE 7

OUTPUT DATA SUMMARY

Peak heating, MBH, by month

Peak cooling, tons, by month

Total base electric load in kW

Monthly and annual loads

- Heating in MBTU
- Heating hours
- Cooling ton-hours
- Cooling hours
- Base A electric load in kW h
- Base C electric load in kW h
- Total base electric load in kW h
- Minimum room temperature °F
- Maximum room temperature °F

Unit values of building energy peaks and consumption

- Heating peak	Btu/Hr./ sq. Ft.
- Heating consumption	MBTU/Sq. ft.
- Full load heating	Hours (equivalent)/yr
- Cooling peak	Tons/1000 Sq. ft.
- Full load cooling	Hours/hr (equivalent)
- Electric peak	Watts/Sq. ft.
- Electric consumption	kWh/Sq. ft.
- Full load electric	Hrs/yr (equivalent)

CHAPTER 5

SUMMARY AND ANALYSIS OF THE RESULTS

5.1 Summary and Discussion of the Results

The zone-by-zone and total annual energy consumption summary for the 11 variations considered is Shown in Table 5.1 and Figure 5.1.

5.1.1 Heating Energy Requirement

From Fig. 5.1, for annual heating energy consumption, alternatives 2, 4, 6 and 11 resulted in an increase, while 5, 7 resulted in a decrease, and 3, 9 and 10 resulted in a marginal decrease with respect to the base case. The percentage changes in the heating energy and cost in comparison with the base case, are shown in Table 5.2. The alternative #8 provides the least heating energy consumption. The natural gas costs were based on the 1980 rates, for Montreal, Canada.

5.1.2 Cooling Energy Requirement

The annual cooling energy consumption and cost data are shown in Table 5.3. The alternative #9 provides the least cooling energy consumption. The cooling costs are calculated assuming a coefficient of performance (C.O.P.) of 3.75, and electrical consumption and demand charges for Montreal, Canada, in 1980.

TABLE 5.1

ANNUAL ENERGY CONSUMPTION SUMMARY
FOR VARIOUS WALL ASSEMBLIES (SEE FIG. 5.1)

ZONE	ITEM	1	2	3	4	5	6	7	8	9	10	11	enclosure alternativ
North 1	HTG, MBH	2,841,111	3,125,695	2,726,940	3,183,714	2,134,516	3,474,375	2,425,201	2,026,560	2,843,913	2,735,130	3,079,693	
2	incl HUM	5,510	-	-	-	-	-	-	-	-	-	-	
3	CLG, TN/HR	52,720	51,878	53,807	68,255	64,886	67,769	64,443	65,057	38,975	39,639	66,606	
4	TOT.EL kWH	976,571	979,854	983,454	1,018,169	1,007,765	1,016,583	1,006,032	1,008,395	954,722	956,003	1,009,860	
East 1	"	2,450,098	2,730,165	2,355,965	2,754,609	1,843,857	3,006,536	2,095,753	1,749,709	2,452,885	2,358,640	2,660,556	
2		-	-	-	-	-	-	-	-	-	-	-	
3		87,319	87,313	87,342	87,859	86,506	87,851	87,848	87,858	80,771	80,891	85,858	
4		1,042,452	1,073,414	1,042,933	1,055,318	1,080,875	1,054,605	1,054,695	1,055,570	1,003,729	1,004,450	1,046,021	
South 1	"	2,834,909	3,125,695	2,726,940	3,183,714	2,134,516	3,474,375	2,425,201	2,026,560	2,834,909	2,726,940	3,075,739	
2		6,200	-	-	-	-	-	-	-	-	-	-	
3		105,765	106,616	107,012	112,645	111,130	112,509	110,924	111,205	86,763	86,921	109,876	
4		1,320,883	1,329,416	1,330,905	1,351,562	1,344,890	1,350,748	1,344,023	1,345,209	1,274,266	1,274,882	1,349,474	
West 1	"	2,450,098	2,730,165	2,355,965	2,754,609	1,843,857	3,006,536	2,095,753	1,749,709	2,450,133	2,355,985	2,660,480	
2		-	-	-	-	-	-	-	-	-	-	-	
3		83,061	82,595	83,240	86,715	87,857	86,373	86,095	86,689	73,158	73,349	84,683	
4		1,067,403	1,066,007	1,067,925	1,083,900	1,055,151	1,082,738	1,079,634	1,081,479	1,032,263	1,032,940	1,081,839	
Core 1	"	-	-	-	-	-	-	-	-	-	-	-	
2		5,143	5,143	5,143	5,143	5,143	5,143	5,143	5,143	5,143	5,143	5,143	
3		41,331	41,331	41,331	41,331	41,331	41,331	41,331	41,331	41,331	41,331	41,331	
4		1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	1,573,570	
TOTAL 1	HTG, incl	10,576,216	11,683,571	10,165,810	11,876,646	7,956,746	12,961,822	9,071,908	7,552,528	10,581,840	10,972,724	11,476,468	
2	HUM,MBH HTG.	-	-	-	-	-	-	-	-	5,143	5,143	5,143	
3	CLG,TN/HR	372,916	372,453	375,452	399,525	394,430	398,553	393,361	394,860	323,718	324,851	391,074	
4	Elect.	5,980,829	6,022,211	5,998,737	6,082,449	6,062,181	6,078,194	6,057,884	6,064,173	5,838,550	5,841,845	6,060,764	

HTG Heating (MBH)
HUM Humidif cation (MBH)
CLG Cooling
EL or ELECT Electrical (kWh/yr)

Column 1 indicated the base case

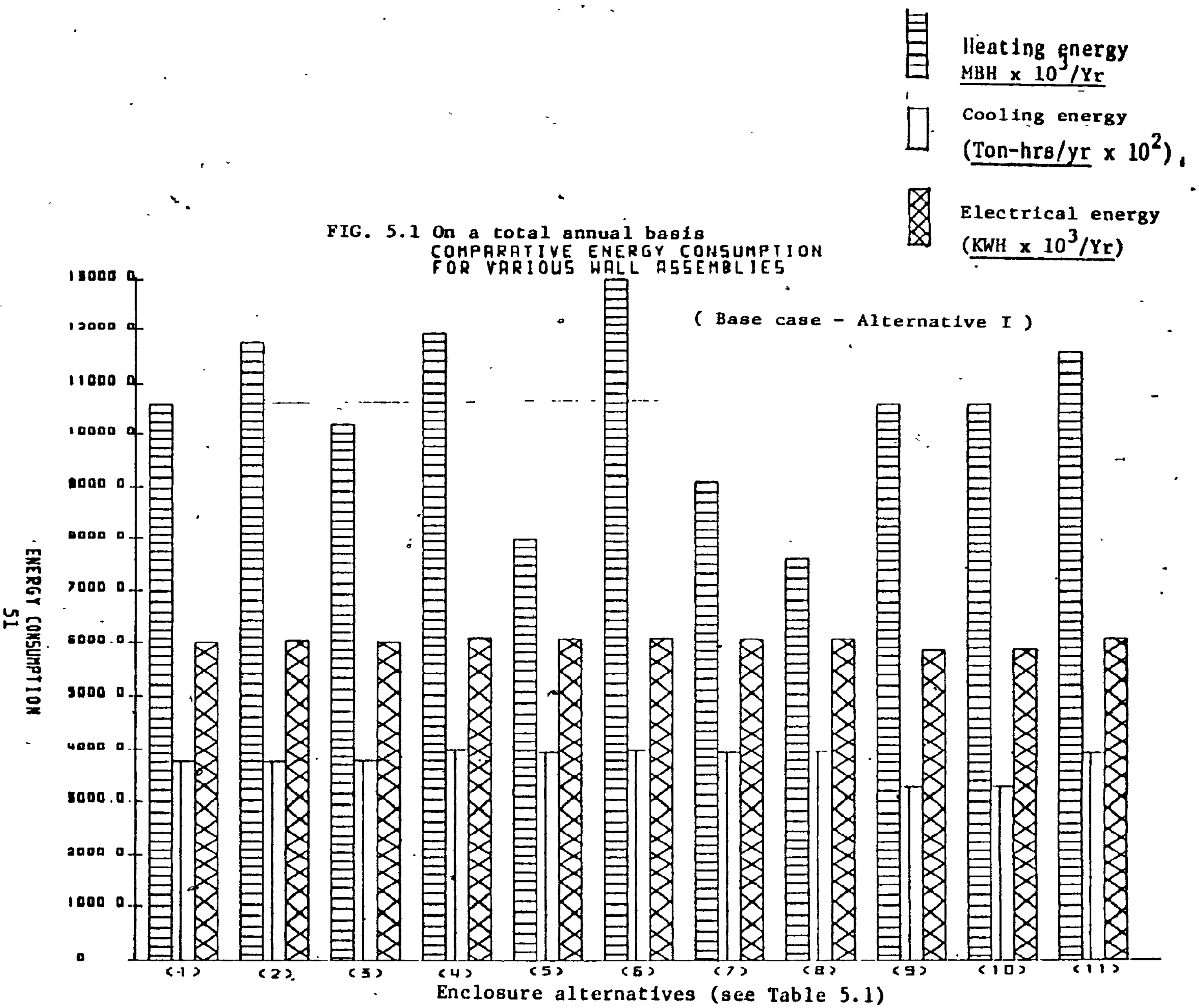


FIG. 5.1 On a total annual basis
COMPARATIVE ENERGY CONSUMPTION
FOR VARIOUS WALL ASSEMBLIES

TABLE 5.2

COMPARATIVE ANNUAL HEATING ENERGY AND
COST FOR VARIOUS WALL ASSEMBLIES

ALT	ANNUAL ENERGY MBH	Δ % MBH	TOTAL COST* PER YEAR	Δ % COST
1	10,576,216	-----	39,132	-----
2	11,683,571	10.47	43,229	10.47
3	10,165,810	-3.88	37,613	-3.88
4	11,876,646	12.30	43,944	12.30
5	7,945,746	-24.77	29,440	-24.77
6	12,961,822	22.56	47,959	22.56
7	9,071,908	-14.22	33,566	-14.22
8	7,552,528	-28.59	27,944	-28.59
9	10,581,840	0.05	39,153	0.05
10	10,572,724	-0.03	39,119	-0.03
11	11,476,468	8.51	42,463	8.51

* 1 MCF = 10^3 MBTU at $3.70/MCF (1980 costs - Montreal,
(natural gas) Canada)

TABLE 5.3

COMPARATIVE ANNUAL COOLING ENERGY AND
COST FOR VARIOUS WALL ASSEMBLIES

ALT	ANNUAL ENERGY ton - hr	Δ % ton - hr	TOTAL COST ** PER YEAR	Δ % COST
1	372,916	----	3,729	-----
2	372,453	- 0.12	3,725	- 0.12
3	375,452	0.68	3,755	0.62
4	399,525	7.14	3,995	7.14
5	394,430	5.77	3,944	5.77
6	398,553	6.87	3,986	6.87
7	393,361	5.48	3,934	5.48
8	394,860	5.88	3,949	5.88
9	323,718	-13.19	3,237	-13.19
10	324,851	-12.89	3,249	-12.89
11	391,074	4.87	3,911	4.87

** 1 ton-hr = 0.94 kWh
(C.O.P. = 3.75)
1981 Hydro-Quebec electrical rates have been applied

5.1.3 Electrical Energy Requirement

The electrical energy consumption and cost data are shown in Table 5.4. The electrical energy included the lighting, fan and pump energy input. The estimates demand for the building (from the simulation program) is 1,808 kW/yr. The consumption and demand costs are calculated from the Hydro-Quebec rates, for Montreal, 1980.

5.1.4 Total Energy Requirement

The total energy consumption is calculated by the summation of the annual heating, cooling and electrical energy requirements (see table 5.5 and Fig. 5.2). The variation of the total energy requirement for the alternatives considered (in comparison with the design condition) is observed to be very limited (-8.29% to +8.70%) indicating the insignificance of the effects of the selected enclosure system variations.

5.1.5 Effects of the Wall Insulation Thickness and Glazing Types

The effects of the variation of the wall insulation thickness on the annual heating and cooling energy are shown in Fig. 5.3 and 5.4 respectively.

TABLE 5.4

COMPARATIVE ELECTRICAL ENERGY CONSUMPTION
FOR VARIOUS WALL ASSEMBLIES

ALT	ELECTRICAL ENERGY CONSUMPTION* kWh	Δ % kWh	TOTAL COST PER YEAR**	Δ % COST
1	5,980,829	----	80,593	----
2	6,022,211	0.71	81,007	0.51
3	5,998,737	0.3	80,772	0.22
4	6,082,499	1.7	81,610	1.26
5	6,062,181	1.4	81,407	1.01
6	6,078,194	1.6	81,567	1.2
7	6,057,884	1.3	81,364	0.96
8	6,064,173	1.4	81,427	1.03
9	5,838,550	-2.4	79,170	-1.76
10	5,841,845	-2.3	79,203	-1.72
11	6,060,764	1.3	81,392	0.99

* Lighting plus power input for fans, pumps (excluding chiller energy consumption)

** Billing demand is 1,808 kW/year (from the simulation program)
1981 Hydro-Quebec rates have been applied (for consumption and demand)

TABLE 5.5

COMPARATIVE TOTAL ENERGY CONSUMPTION
AND COST FOR VARIOUS WALL ASSEMBLIES

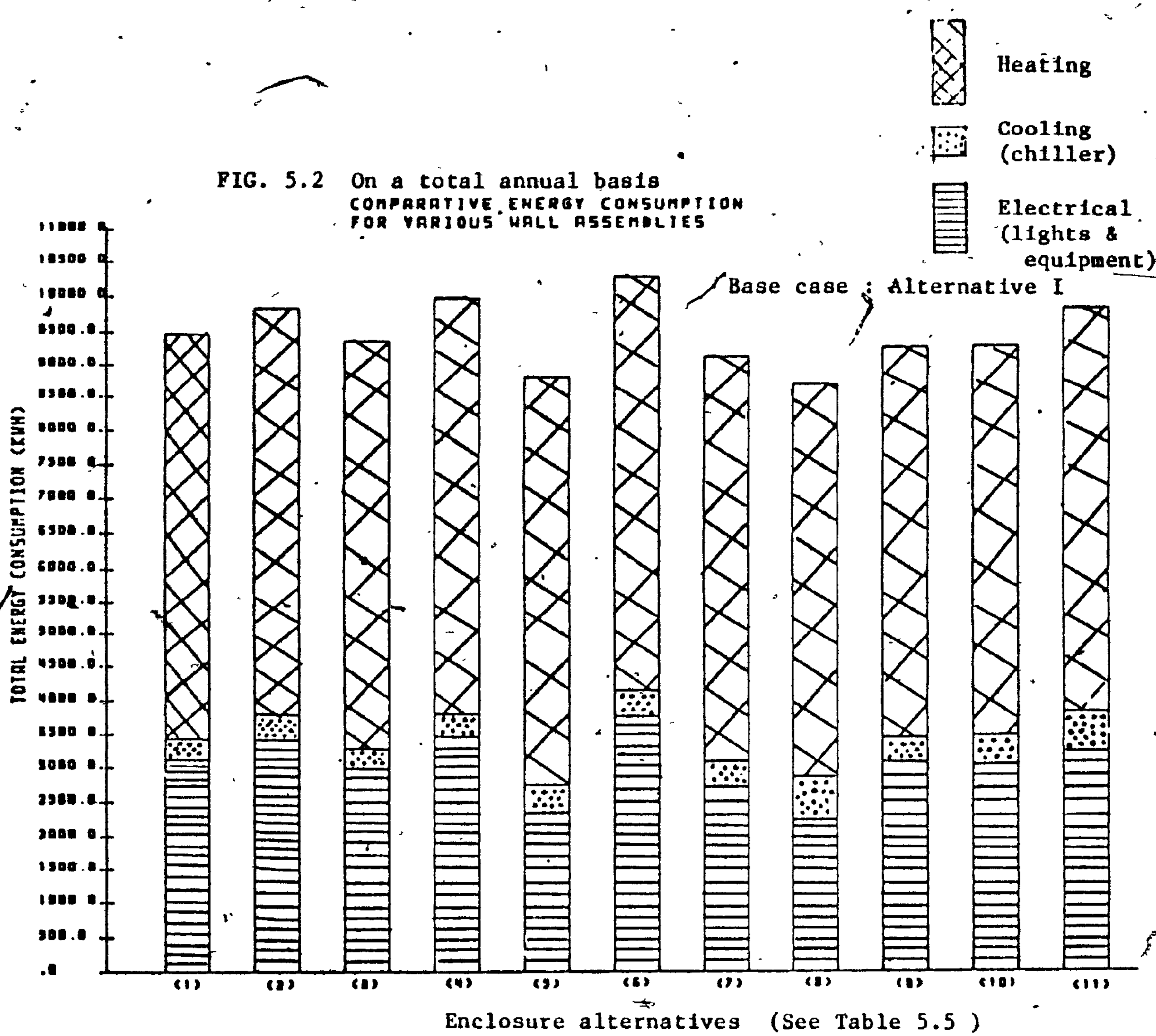
ALT	ANNUAL ENERGY* kWh	Δ% kWh	TOTAL COST** $/YEAR	Δ% COST	X kWh/Ft^2
1	9,429,278	0	123,454	0	28.33
2	9,794,678	3.88	127,961	3.65	29.43
3	9,329,316	-1.06	122,140	-1.06	28.03
4	9,936,915	5.38	129,549	4.94	29.86
5	8,763,304	-7.06	114,791	-7.02	26.33
6	10,249,653	8.70	133,512	8.15	30.80
7	9,084,744	-3.65	118,864	-3.72	27.30
8	8,647,265	-8.29	113,320	-8.21	25.98
9	9,242,519	-1.98	121,560	-1.53	27.77
10	9,244,205	-1.96	121,571	-1.53	27.78
11	9,790,010	3.83	127,766	3.49	29.42

* For heating - 1 kW h = 3.413 MBTU
For cooling - 1 kW h = (ton Hr x 12)/(3.413 C.O.P.)
C.O.P. = 3.75

** Sum of the heating, cooling and electrical costs (from tables ...., ..., ..., respectively)

X Floor area = 332,787 sq. Ft

FIG. 5.2 On a total annual basis
COMPARATIVE ENERGY CONSUMPTION
FOR VARIOUS WALL ASSEMBLIES



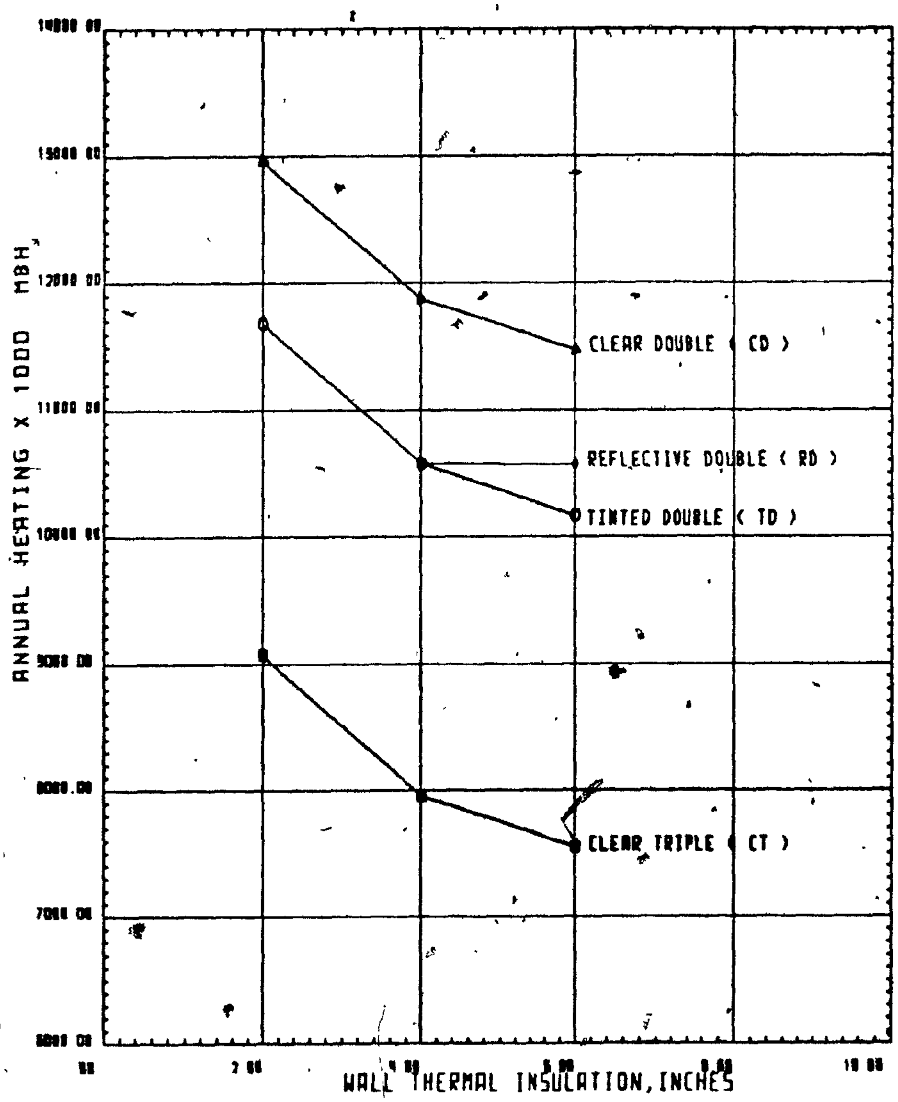


FIG. 5.3 EFFECTS OF THE WALL INSULATION THICKNESS ON THE ANNUAL HEATING ENERGY CONSUMPTION

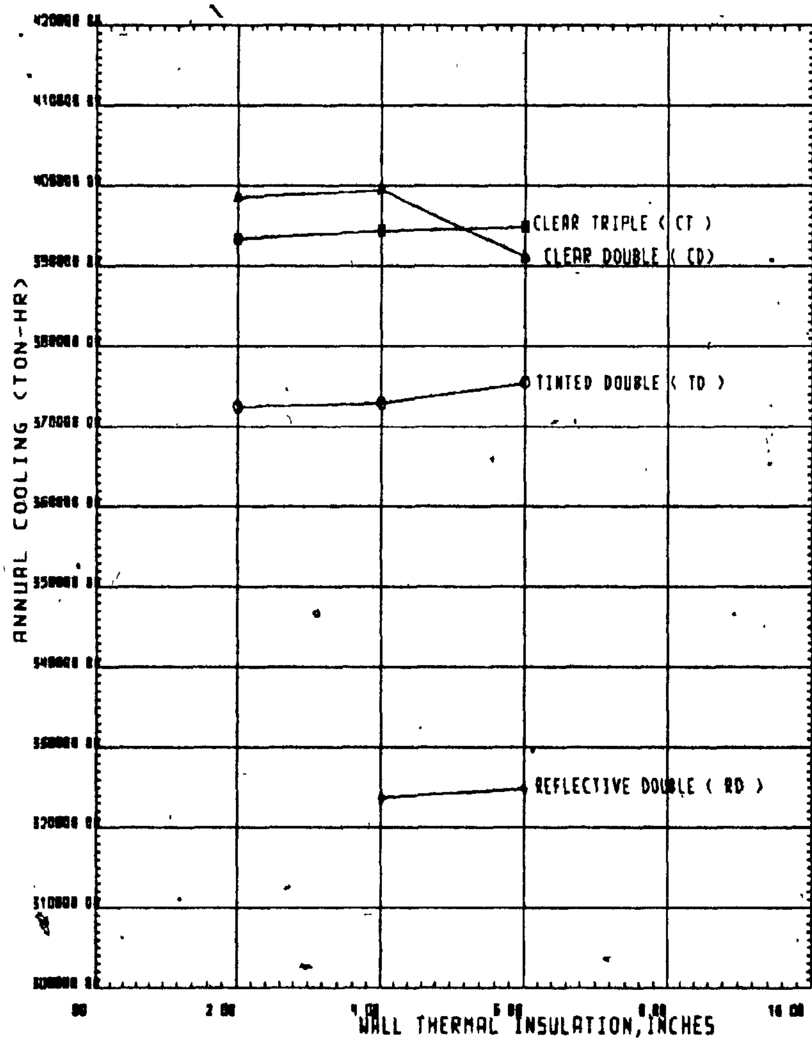


FIG. 5.4 <u>EFFECTS OF THE GLAZING VARIATIONS ON THE ANNUAL ENERGY CONSUMPTION</u>

As expected, the annual heating energy requirement decreased with the increase in the wall insulation thickness and the clear triple glazing (U = 0.31; S.C. = 0.71) provided the least heating requirement.

For the cooling application, the reflective double glazing (U = .37; S.C. = .38) provided the least cooling energy; this reduction can be attributed to the characteristics of the glazing, which reflects the solar radiation (minimizing the solar heat gain), while providing a path for some of the internal heat gains, more effectively than the other types of the glazing considered in this analysis.

5.1.6 Monthly Load Requirements

Typical monthly heating and cooling load variations (alternative #11) are shown in Fig. 5.5. As expected, peak heating load occurs in January and the cooling load in July, and the variations were reasonably uniform (no sudden changes).

Typical monthly zone-by-zone cooling load variations are shown in Fig. 5.6. Due to relatively high glazing area (52%), the south zone has the highest cooling load, from the solar heat gains, in comparison with the other zones.

FIG. 5.5 TYPICAL MONTHLY LOAD VARIATIONS
FOR ALTERNATIVE No. 11

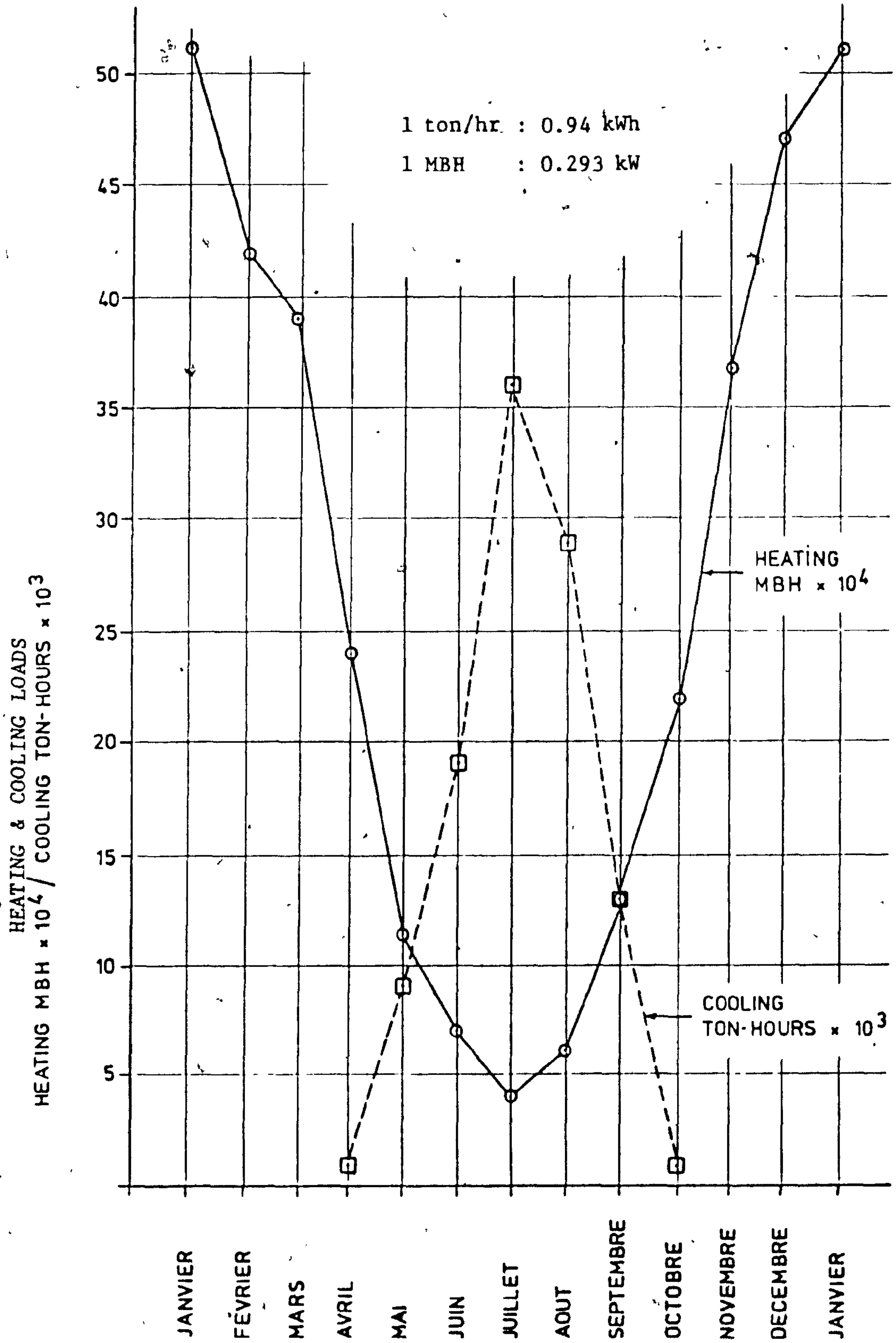
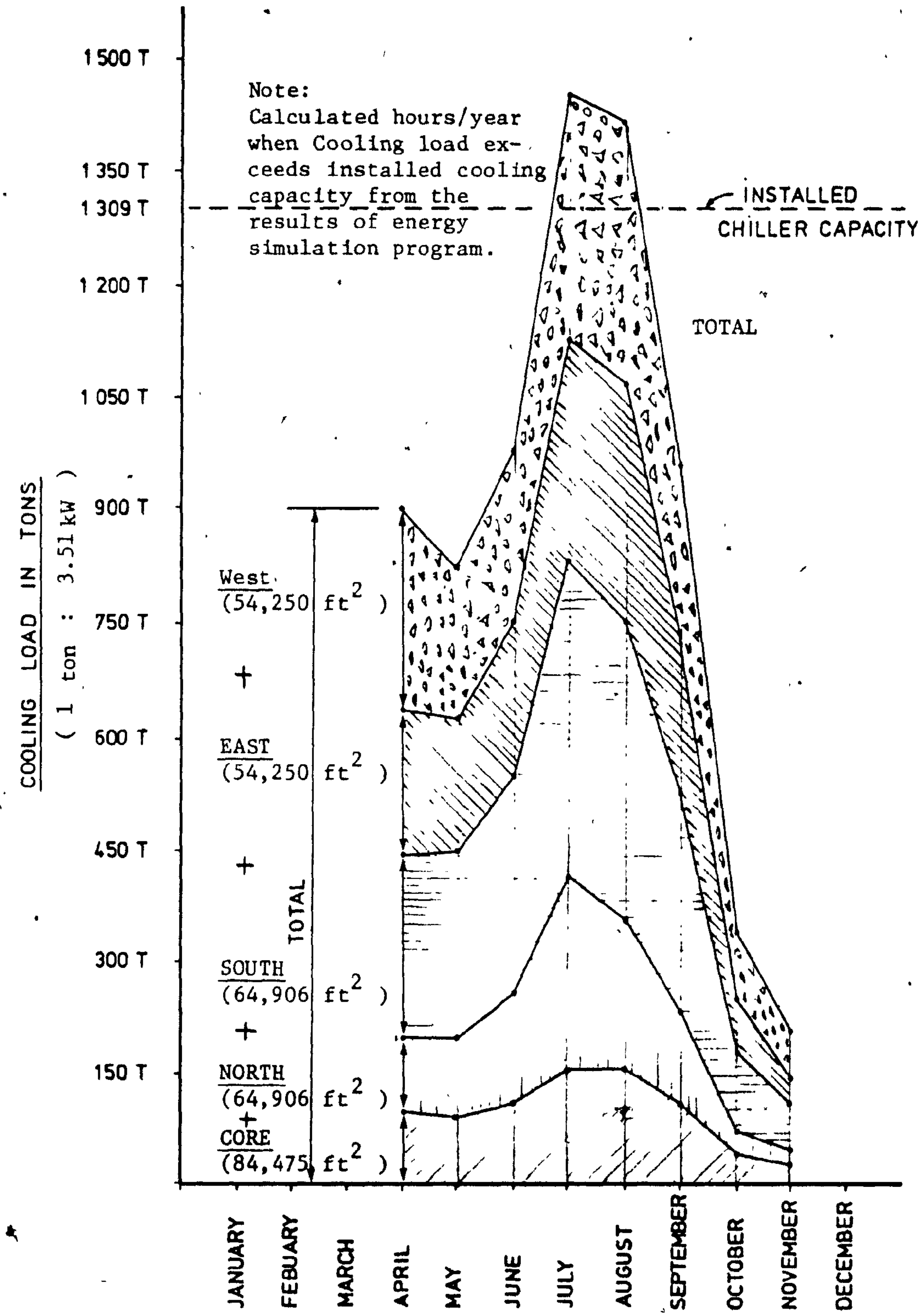


FIG.5.6 TYPICAL MONTHLY ZONE-BY-ZONE COOLING LOAD VARIATIONS FOR ALTERNATIVE No. 1



5.2 Cost Analysis

In this section, the capital cost estimates and capital investment for various alternatives is presented. Then, the discounted payback period calculations are performed with the capital and energy cost data.

5.2.1 Heating Plant Costs

The heating plant capacity and cost data for the alternatives, is shown in Table 5.6. To determine the boiler output capacity, the heat loss from the piping (15% of the building heating requirement), and the boiler efficiency (80% between 70-100% load) were considered. Two boilers, one for 60% and the other for 40% of the required heating load were selected. The plant costs were obtained from the boiler manufacturers, for various load conditions.

5.2.2 Chiller Costs

The chiller costs for various types of glazing considered are shown in Table 5.7. In establishing the chiller capital costs, the availability of a standard chiller of a given capacity was one of the factors. For the cooling tonnage between 1660 and 1466 (for clear double and clear triple glazing types), the selection of a single

TABLE 5.6 – HEATING PLANT CAPACITY AND COST DATA

Art.	Peak heating MBH	15% Pipe Loss	Input required MBH using 80% efficiency	Unit required		Available unit MBH		Installed Cost	Cost/SQ. Ft.
				60%	40%	60%	40%		
1	4435	665	6,375	3,825	2,550	4000	3000	61,760	.191
2	4601	690	6,613	3,968	2,645	4000	3000	61,760	.191
3	3672	550	5,278	3,167	2,111	3000	3000	59,175	.183
4	4290	643	6,166	3,700	3,488	4000	3000	61,760	.191
5	2874	431	4,131	2,479	1,652	3000	2000	55,687	.173
6	4682	702	6,730	4,038	2,692	4000	3000	61,760	.191
7	3266	490	4,695	2,817	1,878	3000	2000	55,687	.173
8	2728	409	3,921	2,352	1.569	3000	2000	55,687	.173
9	5392	808	7,750	4,650	3,100	5000	3000	64,345	.199
10	5246	787	7,541	4,524	3,017	5000	3000	64,345	.199
11	4775	716	6,864	4,118	2,746	4000	3000	61,760	.191

TABLE 5.7

GLASS TYPE vs CHILLER CAPITAL COSTS
1981

GLASS TYPE	DOUBLE CLEAR	TRIPLE CLEAR	SOLAR BRONZE	REFLECTIVE FILM
Tons Cooling	1660	1466	1288	1034
One Machine	Poor engineering practise to use one only machine for these two selections.			
$ Capital Cost			$208,000	$180,000
$/ ton			$161.50	$174.08
$/ SQ. Ft.			$ 0.64	$ 0.56
Two Machines (Equal)				
$ Capital Cost	$312,000	$304,000	$244,000	$224,000
$/ ton	$187.95	$207.37	$184.49	$216.63
$/ SQ. Ft.	$ 0.97	$ 0.94	$ 0.76	$ 0.69

Note: Building area: 322,787 SQ. Ft.

chiller was not considered to be a good practice. For lower capacities (1288 and 1034 tons) a single chiller may be used. The cost data, for the use of two appropriate chillers, for each of the 4 glazing types considered, was developed.

5.2.3 Wall Panel Assembly Costs

The wall panel assembly costs for the combinations of the wall insulation and glazing types considered, are shown in Table 5.8. This information was obtained from the wall panel manufacturers.

5.2.4 Payback Period

The simple payback period summary, for the alternatives considered, is shown in Table 5.9. Due to relatively low energy costs in Canada, the payback period for the alternatives considered are well over 20 years; consequently, none of the alternatives are economic, in this case.

5.2.5 Discounted Payback Period

The discounted payback period for each of the alternatives is calculated as follows:

TABLE 5.8

COMPARATIVE COSTS (1981)
WALL PANEL ASSEMBLY

Glass 52% / Panel 48%	Clear Double	Tinted Double (base case)	Reflective Double	Clear Triple
2" Insul. glass fibre	11.10 / 22.02	11.94 / 23.70	12.55 / 24.90	12.55 / 24.90
4" Insul. (base case)	11.25 / 22.32	12.09 / 24.00	12.70 / 25.20	12.70 / 25.20
6" Insul.	11.40 / 22.62	12.24 / 24.30	12.85 / 25.50	12.85 / 25.50

Floor area: 322,787

Wall area : 162,654

Cost $ / / SQ. Ft

floor area / wall area

TABLE 5.9 - COMPARATIVE COST DATA AND PAYBACK PERIOD

	Capital Costs ($\$/ft^2$)					Operation ($\$/ft^2/yr$)		
Alternative N°	Heating Plant Unit Cost	Cooling Plant Unit Cost	Enclosure Unit Cost	Total Unit Cost	Change in Capital Cost	Total Energy Cost	Change in the Energy Cost	Simple Payback Period (yrs)
1	0.191	0.760	12.09	13.041	-	0.376	-	
2	0.191	0.760	11.94	12.891	-0.15	0.390	+0.014	
3	0.183	0.760	12.24	13.182	+0.142	0.372	-0.004	35.5
4	0.191	0.970	11.25	12.411	-0.63	0.374	-0.002	
5	0.173	0.940	12.70	13.812	+0.772	0.348	-0.028	27.57
6	0.191	0.970	11.10	12.261	-0.780	0.407	+0.031	
7	0.173	0.940	12.55	13.663	+0.662	0.361	-0.015	44.13
8	0.183	0.940	12.85	13.973	+0.932	0.344	-0.032	29.13
9	0.191	0.690	12.70	13.581	+0.540	0.371	-0.005	
10	0.191	0.690	12.85	13.731	+0.690	0.371	-0.005	
11	0.191	0.97	11.40	12.561	-0.480	0.382	+0.006	

*** Simple payback period (yrs)** : $\dfrac{\text{Capital Cost Investment } (\$/ft^2)}{\text{Operation Cost Saving } (\$/ft^2 yr)}$

Assumptions

Return on investment (R) = 15%

Inflation rate for natural gas costs $(\phi_{gas}) = 16\%$

Inflation rate for electrical energy costs $(\phi_{ele}) = 17\%$

$$\sum_{Y=1}^{Y:P} (\text{Energy Savings})/\text{yr} = \Delta\$c$$

Y - year

P - payback period (discounted)

Δ\$c - additional capital costs (in comparison with base case)

The discounted payback periods for the alternatives considered, for different levels of energy costs, are shown in Table 5.10. From this table, it is obvious that the payback periods with the present energy costs are very long; consequently, for this period, none of the alternatives are economically justified.

The alternatives 5 and 8 could be economical if the total eneregy costs were four times the 1980 rates used in this analysis.

TABLE 5.10

DISCOUNTED PAYBACK PERIOD FOR THE ALTERNATIVES
FOR DIFFERENT ENERGY COST LEVELS

ALT.	1xENERGY COST *	2xENERGY COST *	3xENERGY COST *	4xENERGY COST *
1	--	--	--	--
2	--	--	--	--
3	26	13	9	7
4	--	--	--	--
5	22	12	8	6
6	--	--	--	--
7	>30	18	12	10
8	22	12	8	6
9	>30	27	18	15
10	>30	>30	24	19
11	--	--	--	--

* Energy costs indicated in Tables 5.3 to 5.4 (1980 rates)

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6. CONCLUSIONS AND RECOMMENDATIONS

The major objective of this study is to perform the energy requirement and cost analysis for an existing office buildings, for selected enclosure system alternatives.

1. As expected, the heating requirements for the building constituted a major portion of the total annual energy requirement, due to the climatic conditions for the location; consequently, for a given glazing percentage, the wall insulation thickness is the most significant parameter in determining the total energy requirement.

2. Among the glazing types considered, as expected, the clear triple glazing (best thermal resistance) with 6" - wall insulation (highest thermal resistance - alternative #8 which is the alternative for the least heating requirement) provided the least total energy. However, the least cooling energy requirement was provided by the alternative #9 (reflective double glazing with 4" insulation), due to the solar heat reflection characteristics of the glazing. Consequently, one can conclude that, for cases where the cooling load is predominant, the reflective double glazing may be a better choice.

3. Based on the discounted payback period analysis, for this project, none of the enclosure alternatives considered are economical (at the energy costs considered) which also indicates that the original design of the building (base case - alternative #1) is energy effective.

<u>Recommendation:</u>

For buildings with predominent heating load, analysis of the alternate heating, cooling and electrical system operation strategies may result in better energy and cost savings in comparison with the analysis of alternate enclosure systems, at the present energy costs in Canada; consequently, such an analysis is recommended for this project.

REFERENCES

REFERENCES

1. Cooling and Heating Load Calculation Manual ASHRAE, 1979.

2. Reference Manual for Energy Systems Analysis - series of Programs (Meriwether) Public Works Canada, 1980.

3. ASHRAE Handbook of fundamentals 1977 & 1981.

4. ASHRAE Handbook, Equipment 1979 & 1983.

5. ASHRAE Handbook, systems 1980.

6. ASHRAE Handbook, Applications 1978 & 1982.

APPENDIX A-1

APPENDIX A-1

Computer print-out showing input data and results of ERE analysis for the East zone of Run No. 7 (2" glass fibre wall insulation and triple clear glazing) and for the West zone of Run No. 7 (2" glass fibre wall insulation and triple clear glazing).

RUN No. 7

EAST ZONE

```
ENERGY  REQUIREMENT  ESTIMATE  PROGRAM  FOR

    EAST RUN 7  TR 6L  2F8                                                                            MAR. 29/80

SYS TP    FLOOR    SOLAR     PIP   PCIPL    PILT  PCILTR  PCLTRH    PIE    PIM   PCIML    PPI    PPD   PBEA  PBER  PREC KY
   5     54250.   2570.0   135.0    44.    585.0    15.      0.     0.0   27.7    15.    0.0    0.0   171.    0.  122.   5

 SOLAR AREA PERCENTAGES                  TIME                      SHUTOFF AND PRIMARY FUEL INTERRUPTION TEMPERATURES -- NO. OF DAYS
  D1  D2  D3  D4  D5  D6  D7  D8   H  SH MO HR    HSCAP    CSCAP   INTHST  INTCST  PFIT HRS  JA FE MA AP MA JU JU AU SE OC NO DE
 17.  0. 83.  0.  0.  0.  0.  0.  0.  0.  6 13  999999.    1302.      65      50       0    0   0  0  0  0  0  0  0  0  0  0  0  0

HEATING LOADS                                                            COOLING LOADS
 HIDB  HIDP  HODB  HODP     HOTL  TLHDU  HOSTU  TLHDL  HOSTL             CIDB  CIDP  CODB  CODP     CDTS  COST  HRCO  SCOST  SHRCD
  68.    0.  -25.    0.    757.0     0.     0.     0.     0.             -78.    0.   85.   66.     57.0   55.   54.     0.     0.

  RATRLM  RASOLM  SFDT  RFDT   HSF KHSF
    0.0     0.0   -5.0   1.6    0.    0

AIRFLOW DATA
     TSA     ZVFCM    ZVFHM   OAVMAX   OAMINC   OAMINM   OAMINS  TLEU  TLEL  TLCOU  CDTU  TLCOL  COTL  COTUO  VVMAF  EFFS  EFFL
  76230.       0.       0.   76230.    7623.    7623.      0.   -99.  -99.     0.    0.     0.    0.     0.    40.    0.    0.

ADDITIONAL SYSTEM DATA
 RECR  NORMAL OPERATION......  SETBACK OPERATION.....                                                    HUMID RS
 HEAT  MX            MN        MX            MN           EL  SY  PCT REDUCTION IN PEAK PROCESS........ PR  HI HI LO HM AR   INFIL IN
 RATO  TM SUPL HT   TM SUPL HT TM SUPL HT   TM SUPL HT   KY  KY   J  F  M  A  M  J  J  A  S  O  N  D  KY  DP AM AM KY KY     CFM KY
 0.0   65       0. -25   757.  65       0. -25    757.   0   0   0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.  0   0  0  0  1  3      0.  0

SHUTOFF AND SETBACK TIME SCHEDULES
NO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO

 1    1, 7 18, 7   1/12    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0
 2    1,24  0, 0   1/12    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0

PERCENTAGE VARIATION PROFILES

   1   0,, 8 100,, 3  80,, 1  40,, 1  80,, 1 100,, 3  10,, 4   0,, 3   0,, 0   0,, 0   0,, 0   0,, 0  PEOPLE  WEEK
   2   0,,24   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0  PEOPLE  WKEND HOL
   3   5,, 7  10,, 1  20,, 1  90,, 3  80,, 2  90,, 3  70,, 2  60,, 1  40,, 1  30,, 1   5,, 2   0,, 0  LIGHT OE WEEK
   4   5,,24   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0   0,, 0  LIGHT OE WKEND HOL

DAY NUMBER FOR JANUARY 1 IS  3    LEAP YEAR KEY IS  1
HOL   1/ 1, 1   4/ 4, 0   4/ 6, 1   5/26, 0   6/24, 0   9/ 1, 0  10/13, 0  12/25, 1   0/ 0, 0   0/ 0, 0   0/ 0, 0   0/ 0, 0

DAY TYPE DESCRIPTION AND DISTRIBUTION
 DT  PCT VARIATION PROFILE NUMBERS...........  KEY    TIME SCHEDULES   SBT  TSY  J F M A M J J A S O N D   S M T W T F S  H
 NO  PEO LTS EQP MSC IPR DPR SEA SER SEC VOA   DA    OA MS CS SB OP   SCH  SCH

  1   1   3   0   3   0   0   3   0   0   0    0     1  0  1  0  0    0    0   0 0 0 0 0 0 0 0 0 0 0 0   0 0 0 0 0
  2   2   4   0   4   0   0   4   0   0   0    0     2  0  2  0  0    0    0   0 0 0 0 0 0 0 0 0 0 0 0   0             0  0

SPECIAL HOURLY PRINTOUT
 MO  DAY/DAY   MO  DAY/DAY   MO  DAY/DAY   MO  DAY/DAY   PRINT KEY
  0    0   0    0    0   0    0    0   0    0    0   0       0
```

PERCENTAGE VARIATION PROFILES

NUMBER	12 M	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12 N	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
1	0.	0.	0.	0.	0.	0.	0.	0.	100.	100.	100.	80.	40.	80.	100.	100.	100.	10.	10.	10.	10.	0.	0.	0.
3	5.	5.	5.	5.	5.	5.	5.	10.	20.	90.	90.	90.	80.	60.	90.	90.	90.	70.	70.	60.	40.	30.	5.	5.
4	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.

SHUTOFF AND SETBACK TIME SCHEDULE 1

	12 M	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12 N	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
JAN	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
FEB	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
MAR	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
APR	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
JUN	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
JUL	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
AUG	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
SEP	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
OCT	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
NOV	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1

SHUTOFF AND SETBACK TIME SCHEDULE 2

	12 M	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12 N	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
JAN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FEB	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MAR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
APR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JUN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JUL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AUG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SEP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OCT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NOV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

POOR COPY
COPIE DE QUALITEE INFERIEURE

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

EAST RUN 7 TR GL 2F8 MAR. 29/80

SYSTEM TYPE 8 STD. VARIABLE VOLUME

UNIT VALUES OF INPUT DATA (FLOOR AREA = 54250. SQFT)

	LATENT	SENSIBLE	
SOLAR LOAD		52.90	BTUH/SQFT
TRANSMISSION LOSS		0.145	BTUH/F-SQFT
TRANSMISSION GAIN		0.180	BTUH/F-SQFT
TOTAL INTERNAL LOAD	1.18	12.07	BTUH/SQFT
PEOPLE	1.10	1.40	BTUH/SQFT
LIGHTS		10.23	BTUH/SQFT
EQUIPMENT		0.0	BTUH/SQFT
MISCELLANEOUS	0.08	0.43	BTUH/SQFT
MINIMUM O/A, COOLING	4.10	1.06	BTUH/SQFT
OR ...		0.141	CFM/SQFT
OR ...		10.00	PCT OF TOTAL
PEAK COOLING LOAD	5.16	69.12	BTUH/SQFT
ROOM SENS ONLY		64.49	BTUH/SQFT
TOTAL		6.19	TONS/1000 SQFT
OR ...		161.55	SQFT/TON
COOLING CAPACITY		24.00	TONS/1000 SQFT
OR ...		41.67	SQFT/TON
ROOM SENS ONLY		34.90	BTUH/SQFT
MINIMUM O/A, HEATING	0.0	14.11	BTUH/SQFT
OR ...		0.141	CFM/SQFT
OR ...		10.00	PCT OF TOTAL
PEAK HEATING LOAD	0.0	27.88	BTUH/SQFT
HEATING CAPACITY		18433.16	BTUH/SQFT
TOTAL PROCESS LOAD		0.0	BTUH/SQFT
INDIRECT		0.0	BTUH/SQFT
DIRECT		0.0	BTUH/SQFT
TOTAL BASE ELEC LOAD		5.40	WATTS/SQFT
SOURCE A		3.15	WATTS/SQFT
SOURCE B		0.0	WATTS/SQFT
SOURCE C		2.25	WATTS/SQFT
TOT PRIMARY AIRFLOW		1.405	CFM/SQFT
OR ...		58.5	CFM/TON

HEATING INSIDE = 68. / 0. OUTSIDE =-25. / 0.

COOLING INSIDE = 78. / 0. OUTSIDE = 85. /66.

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

EAST RUN 7 TR GL 2FG

MAR. 29/80

MONTHLY AND ANNUAL PEAK LOAD VALUES

	PEAK HEATING, MBH		PEAK COOLING, TONS		HUMIDFCN MBH	INDIRECT PROCESS MBH	DIRECT PROCESS MBH	TOT BASE ELECTRIC KW
	RM LOSS	COILS	RM GAIN	COILS				
** JAN **	839.	707.	382.2	0.0	0.	0.	0.	276.
DAY OF MONTH	3	3	9	0	0	0	0	3
TIME OF DAY	6AM	9AM	10AM					10AM
DAY TYPE	1	1	1	0	0	0	0	1
DRY BULB TEMP	-16	-19	-1	0	0	0	0	-18
DEW POINT TEMP	-19	-21	-5	0	0	0	0	-21
** FEB **	944.	856.	878.4	0.0	0.	0.	0.	276.
DAY OF MONTH	11	28	1	0	0	0	0	1
TIME OF DAY	5AM	4AM	10AM					9AM
DAY TYPE	1	1	1	0	0	0	0	1
DRY BULB TEMP	-10	-13	21	0	0	0	0	19
DEW POINT TEMP	-14	-17	15	0	0	0	0	15
** MAR **	1137.	860.	760.8	0.0	0.	0.	0.	276.
DAY OF MONTH	3	1	13	0	0	0	0	3
TIME OF DAY	6AM	6AM	9AM					9AM
DAY TYPE	1	2	1	0	0	0	0	1
DRY BULB TEMP	-3	-4	29	0	0	0	0	-4
DEW POINT TEMP	-6	-6	17	0	0	0	0	-6
** APR **	1311.	488.	833.3	192.1	0.	0.	0.	276.
DAY OF MONTH	7	3	17	28	0	0	0	1
TIME OF DAY	8PM	7AM	9AM	4PM				9AM
DAY TYPE	2	1	1	1	0	0	0	1
DRY BULB TEMP	31	7	33	78	0	0	0	32
DEW POINT TEMP	30	-1	12	29	0	0	0	27
** MAY **	1176.	244.	847.1	178.4	0.	0.	0.	276.
DAY OF MONTH	27	10	14	20	0	0	0	1
TIME OF DAY	4AM	3AM	8AM	4PM				9AM
DAY TYPE	1	2	1	1	0	0	0	1
DRY BULB TEMP	52	36	43	76	0	0	0	48
DEW POINT TEMP	35	30	25	39	0	0	0	37
** JUN **	1127.	193.	860.8	208.8	0.	0.	0.	276.
DAY OF MONTH	23	9	18	3	0	0	0	2
TIME OF DAY	1AM	4AM	8AM	2PM				9AM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	59	42	54	80	0	0	0	52
DEW POINT TEMP	54	40	40	41	0	0	0	48

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

EAST RUN 7 TR GL 2FG MAR. 29/80

MONTHLY AND ANNUAL PEAK LOAD VALUES

	PEAK HEATING, MBH RM LOSS	COILS	PEAK COOLING, TONS RM GAIN	COILS	HUMIDFCN MBH	INDIRECT PROCESS MBH	DIRECT PROCESS MBH	TOT BASE ELECTRIC KW
** JUL **	1112.	185.	862.8	296.3	0.	0.	0.	276.
DAY OF MONTH	7	1	4	28	0	0	0	1
TIME OF DAY	4AM	4AM	8AM	4PM				9AM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	55	43	67	78	0	0	0	57
DEW POINT TEMP	49	41	54	60	0	0	0	46
** AUG **	961.	227.	859.9	314.8	0.	0.	0.	276.
DAY OF MONTH	11	27	8	11	0	0	0	1
TIME OF DAY	4AM	8AM	9AM	12 N				9AM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	58	38	68	77	0	0	0	70
DEW POINT TEMP	56	38	53	62	0	0	0	58
** SEP **	823.	311.	767.1	205.8	0.	0.	0.	276.
DAY OF MONTH	8	13	29	29	0	0	0	2
TIME OF DAY	3AM	6AM	9AM	2PM				9AM
DAY TYPE	1	2	1	1	0	0	0	1
DRY BULB TEMP	41	28	54	80	0	0	0	56
DEW POINT TEMP	37	23	38	41	0	0	0	52
** OCT **	689.	320.	588.1	75.5	0.	0.	0.	276.
DAY OF MONTH	14	27	16	28	0	0	0	1
TIME OF DAY	6AM	2AM	10AM	2PM				9AM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	30	27	39	61	0	0	0	43
DEW POINT TEMP	30	19	29	32	0	0	0	25
** NOV **	707.	614.	382.8	45.3	0.	0.	0.	276.
DAY OF MONTH	26	26	5	6	0	0	0	3
TIME OF DAY	6AM	6AM	10AM	2PM				10AM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	-8	-8	43	58	0	0	0	34
DEW POINT TEMP	-11	-11	31	24	0	0	0	24
** DEC **	951.	757.	235.1	0.0	0.	0.	0.	276.
DAY OF MONTH	27	27	4	0	0	0	0	1
TIME OF DAY	4PM	10AM	11AM					10AM
DAY TYPE	2	2	1	0	0	0	0	1
DRY BULB TEMP	-19	-26	35	0	0	0	0	16
DEW POINT TEMP	-26	-30	22	0	0	0	0	9
** ANN **	1311.	757.	862.8	314.8	0.	0.	0.	276.
MONTH OF YEAR	4	12	7	8	0	0	0	1
DAY OF MONTH	7	27	4	11	0	0	0	3
TIME OF DAY	8PM	10AM	8AM	12 N				10AM
DAY TYPE	2	2	1	1	0	0	0	1
DRY BULB TEMP	31	-26	67	77	0	0	0	-18
DEW POINT TEMP	30	-30	54	62	0	0	0	-21

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

EAST RUN 7 TR OL 2FB

MAR. 29/80

MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT RS EL KWH	AUX F HRS
JAN	352842.	744	0.	0	0.	0.	0.	39601.	0.	45569.	85144.	0
FEB	287827.	672	0.	0	0.	0.	0.	37402.	0.	44232.	81629.	0
MAR	267325.	744	0.	0	0.	0.	0.	39601.	0.	50565.	90159.	0
APR	164926.	703	1228.	20	0.	0.	0.	37813.	0.	49772.	87579.	0
MAY	81954.	680	8830.	147	0.	0.	0.	39601.	0.	51678.	91270.	0
JUN	48344.	556	15930.	184	0.	0.	0.	39395.	0.	50507.	89895.	0
JUL	29395.	436	27686.	226	0.	0.	0.	42766.	0.	53142.	95900.	0
AUG	41456.	531	23819.	199	0.	0.	0.	39601.	0.	51677.	91270.	0
SEP	69978.	637	9363.	119	0.	0.	0.	39395.	0.	49457.	88846.	0
OCT	152657.	744	1185.	38	0.	0.	0.	41183.	0.	49245.	90472.	0
NOV	255112.	720	107.	4	0.	0.	0.	37813.	0.	42677.	80486.	0
DEC	323938.	744	0.	0	0.	0.	0.	39601.	0.	42482.	82077.	0
ANN	2095753.	7910	87848.	937	0.	0.	0.	473769.	0.	581001.	1054695.	0

```
ENERGY  REQUIREMENT  ESTIMATE  PROGRAM  FOR
    EAST RUN 7  TR GL  2F8                                                                                       MAR. 29/80
                             SO OR SB    MO/DY/TIME     NORM OPER    MO/DY/TIME

MIN ROOM TEMP                66.21 F     1/ 1/12 M       68.21 F     1/ 1/12 M
MAX ROOM TEMP               196.86 F     5/27/ 7AM      196.86 F     5/27/ 7AM
MAX ROOM HUMIDITY RATIO      65.20 GR    1/ 3/ 7AM

COUNT OF HOURS ON LIMITING CONDITIONS       HEATING     COOLING
    SPACE LOAD NOT MET (INCL PICKUP LOAD)        0        1966
    SPACE LOAD NOT MET (W/O PICKUP LOAD)         0         976
    SYSTEM CAPACITY EXCEEDED                     0           0
    LONGEST PICKUP PERIOD                        0          10
       LAST HOUR OF OCCURRENCE               0/ 0/      4/ 1/ 4PM
UNIT VALUES OF BUILDING ENERGY PEARS AND CONSUMPTION          ANNUAL EQUIVALENT ENERGY CONSUMPTION =   124417. BTU/SQFT/YR

    HEATING PEAK                      13.95   BTUH/SQFT
    HEATING CONSUMPTION               38.63   MBTU/SQFT
    FULL LOAD HEATING                 2766.   HRS                  PEAK HEATING LOAD DURING SETBACK =       0. MBH

    COOLING PEAK                       5.80   TONS/1000 SQFT
       OR ......                     172.34   SQFT/TON
    COOLING CONSUMPTION                1.62   TON-HRS/SQFT
    FULL LOAD COOLING                  279.   HRS

    PROCESS PEAK                        0.0   BTUH/SQFT
    PROCESS CONSUMPTION                 0.0   MBTU/SQFT
       INDIRECT                         0.0   MBTU/SQFT
       DIRECT                           0.0   MBTU/SQFT
    FULL LOAD PROCESS                    0.   HRS

    ELECTRIC PEAK                      5.09   WATTS/SQFT
    ELECTRIC CONSUMPTION              19.44   KWH/SQFT
    FULL LOAD ELECTRIC                3821.   HRS

MAX SUPPLY AIRFLOW IS     76230. CFM     1/ 3/10AM       MIN SUPPLY AIRFLOW IS     30492. CFM     1/ 1/ 1AM
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ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

EAST RUN 7. TR GL 2FG

.MAR. 29/88

YRHR TIME	MO DY	DT CC	DB DP	SORAD RMIS	TRLOAD RMIL	BHSHRC BHSHRI	ZSHG TZSHG	OACFM DELHR	RTEMP RAT	AMAT RRRA	COST RDST	TSA/ZVFC ZVFR	CCLOAD RCLOAD	CLT RLT	D-PROC I-PROC	HUMID BELEC
*** JAN ***																
88	1	1	-19	1099132.	-870682.	0.	750375.	22836.	78.0	80.0	50.0	60438.	0.	0	0.	0.
9AM	3	2	-21	521925.	63579.	0.	1501863.	0.0	91.9	19.9	55.0	0.	786533.	0	0.	251.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.
*** FEB ***																
1397	2	1	-13	0.	-771051.	0.	-748286.	0.	78.0	84.6	84.6	30492.	0.	0	0.	0.
6AM	28	0	-17	24765.	208.	0.	-87722.	0.0	84.6	8.9	89.6	0.	656067.	0	0.	57.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.
*** MAR ***																
1423	3	2	-4	0.	-682986.	0.	-658221.	0.	78.0	82.7	82.7	30492.	0.	0	0.	0.
6AM	1	6	-6	24765.	208.	0.	-75357.	0.0	82.7	15.6	87.7	0.	580367.	0	0.	57.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.
*** APR ***																
2216	4	1	7	7844514.	-740817.	0.	7153226.	41333.	102.6	80.0	50.0	76230.	0.	1	0.	0.
7AM	3	0	-1	49529.	415.	5751690.	7646065.	0.0	100.9	8.3	55.0	0.	487844.	0	0.	[illegible]
2825	4	1	76	1233972.	-472086.	32102448.	1283811.	76230.	131.4	78.0	50.0	76230.	2308194.	1	0.	0.
4PM	28	1	29	521925.	63579.	21861136.	23755920.	0.0	149.3	24.3	55.0	0.	0.	0	0.	276.
*** MAY ***																
3100	5	2	36	0.	-483397.	0.	-458632.	0.	78.0	97.8	97.8	30492.	0.	0	0.	0.
3AM	10	0	30	24765.	208.	0.	-212213.	0.0	97.8	32.9	102.8	0.	243922.	0	0.	57.
3353	5	1	76	1402701.	-294892.	18958416.	1629733.	76230.	109.4	76.0	50.0	76230.	2140537.	1	0.	0.
4PM	20	4	39	521925.	63579.	13006248.	14900623.	0.0	125.2	36.4	55.0	0.	0.	0	0.	276.
*** JUN ***																
3821	6	1	42	0.	-712148.	0.	-687384.	0.	78.0	132.3	132.3	30492.	0.	0	0.	0.
4AM	9	1	40	24765.	208.	0.	-491431.	0.0	132.3	47.9	137.3	0.	193455.	0	0.	57.
3687	6	1	80	1813259.	-459971.	32371072.	1875213.	76230.	132.4	80.0	50.0	76230.	2469851.	1	0.	0.
2PM	3	3	41	521925.	63579.	22640560.	24534944.	0.0	149.8	39.3	55.0	0.	0.	0	0.	276.

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

EAST RUN 7 TR GL 2F8

MAR. 29/80

YRHR	MO	DT	DB	SORAD	TRLOAD	BHSHRC	ZSHG	OACFM	RTEMP	AMAT	COST	TSA/ZVFO	CCLOAD	CLT	D-PROC	HUMID
TIME	DY	CC	DP	RMIS	RMIL	RHSHRI	YZSHG	DELHR	RAT	RMMA	HOST	ZVFM	RCLOAD	RLT	I-PROC	BELEC
*** JUL ***																
4349	7	1	43	0.	-779441.	0.	-754676.	0.	78.0	141.7	141.7	30492.	0.	0	0.	0.
4AM	1	0	41	24765.	208.	0.	-567134.	0.0	141.7	51.0	146.7	0.	185044.	0	0.	57.
5009	7	1	78	1402701.	-815215.	35035824.	1409410.	76230.	136.5	78.0	50.0	76230.	3556062.	1	0.	0.
4PM	28	4	60	521925.	63579.	24040096.	25934480.	23.71	154.7	55.0	55.0	0.	0.	0	0.	276.
*** AUG ***																
5718	8	1	38	0.	-522934.	0.	-498169.	0.	78.0	104.8	[illegible]	30492.	0.	0	0.	0.
5AM	27	6	38	24765.	208.	0.	-268572.	0.0	104.8	44.2	[illegible]	0.	227100.	0	0.	57.
5341	8	1	77	2449386.	-724717.	48738336.	2151347.	76230.	160.8	77.0	[illegible]	76230.	3777374.	1	0.	0.
12 N	11	2	62	426700.	27260.	34373808.	36268192.	29.47	179.6	54.3	[illegible]	0.	0.	0	0.	259.
*** SEP ***																
6127	9	2	28	0.	-472672.	0.	-447907.	0.	78.0	88.5	88.5	30492.	0.	0	0.	0.
6AM	13	1	23	24765.	208.	0.	-134199.	0.0	88.5	19.7	93.5	0.	311211.	0	0.	57.
6519	9	1	80	1264316.	-414316.	29265920.	1371925.	76230.	126.7	80.0	50.0	76230.	2469851.	1	0.	0.
2PM	29	0	41	521925.	63579.	19963664.	21858048.	0.0	144.1	39.3	55.0	0.	0.	0	0.	274.
*** OCT ***																
7179	10	1	27	0.	-688962.	0.	-664197.	0.	78.0	114.4	114.4	30492.	0.	0	0.	0.
2AM	27	0	19	24765.	208.	0.	-342077.	0.0	114.4	36.8	119.4	0.	319627.	0	0.	57.
7215	10	1	61	831231.	-242584.	7206298.	1110572.	76230.	88.9	61.0	50.0	76230.	905612.	1	0.	0.
2PM	28	4	32	521925.	63579.	4294249.	6188624.	0.0	103.7	27.6	55.0	0.	33644.	0	0.	276.
*** NOV ***																
7903	11	1	-8	0.	-732132.	0.	-707368.	0.	78.0	86.8	86.8	30492.	0.	0	0.	0.
6AM	26	6	-11	24765.	208.	0.	-490859.	0.0	84.8	10.6	89.8	0.	614011.	0	0.	57.
7431	11	1	58	833312.	-173809.	889875.	881428.	62904.	78.0	58.0	50.0	62904.	543492.	0	0.	0.
2PM	6	3	24	521925.	63579.	0.	1563217.	0.0	85.4	19.8	55.0	0.	58878.	0	0.	255.
*** DEC ***																
8651	12	2	-26	2343031.	-987321.	0.	1380473.	0.	78.0	98.6	98.6	30492.	0.	0	0.	0.
10AM	27	5	-30	24765.	208.	0.	2139970.	0.0	98.6	13.5	103.6	0.	757000.	0	0.	57.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.

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RUN No. 7

WEST ZONE

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ENERGY  REQUIREMENT  ESTIMATE  PROGRAM  FOR

   WEST RUN 7  TR GL 2FG                                                                                          MAR. 29/80

SYS TP     FLOOR      SOLAR    -PIP    PCIPL    PILT  PCILTR  PCLTRH     PIE     PIM    PCIML     PPI     PPD     PREA  PREB  PREC KY
  8       54250.     3021.0   136.0      44.   595.0     15.      0.     0.0    27.7      15.     0.0     0.0     171.    0.  136.  5

 SOLAR AREA PERCENTAGES                       TIME                             SHUTOFF AND PRIMARY FUEL INTERRUPTION TEMPERATURES -- NO. OF DAYS
  D1  D2  D3  D4  D5  D6  D7  D8   H  SH MO HR    HSCAP     CSCAP   INTHST  INTCST  PFIT HRS  JA FE MA AP MA JU JU AU SE OC NO DE
  0.  0.  0.  0. 17.  0. 83.  0.  0.  0.  6 13  999999.    1302.      65      50      0    0   0  0  0  0  0  0  0  0  0  0  0  0
HEATING LOADS                                                            COOLING LOADS
 HIDR  HIDP  HDDB  HDDP    HDTL  TLHDU  HDSTU  TLHDL  HDSTL              CIDB  CIDP  CDDB  CDDP    CDTB  CDST  HRCD  SCDST  SHRCD
  68.   0.   -25.   0.    747.0    0.     0.     0.     0.               -78.   0.    85.   66.    57.0   55.   54.     0.     0.

 RATRLH  RASOLH  SFDT  RFDT   HSF KHSF
   0.0     0.0   -5.0   1.6    0.    0

AIRFLOW DATA
   TSA     ZVFCH    ZVFHH   OAVMAX   OAMINC   OAMINH   OAMINS  TLEU  TLEL TLCDU  CDTU TLCDL  CDTL CDTUO VVHAF  EFFS  EFFL
 84389.      0.       0.    84385.    8439.    8439.      0.   -99.  -99.    0.    0.    0.    0.    0.   40.    0.    0.

ADDITIONAL SYSTEM DATA
 RECR  NORMAL OPERATION......  SETBACK OPERATION.....                       HUMID RS
 HEAT  MX          MN          MX          MN        EL  SY  PCT REDUCTION IN PEAK PROCESS....... PR  HI HI LO HM AR  INFIL IN
 RATO  TM SUPL HT  TM SUPL HT  TM SUPL HT  TM SUPL HT  KY  KY    J  F  M  A  M  J  J  A  S  O  N  D  KY  DP AM AM KY KY    CFM KY
 0.0   65       0. -25   757.  65       0. -25   757.   0   0   0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.   0   0  0  0  1  3     0.  0
SHUTOFF AND SETBACK TIME SCHEDULES
NO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO   HR,DR HR,DR  MO/MO
 1    1, 7 19, 7   1/12    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0
 2    1,24  0, 0   1/12    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0    0, 0  0, 0   0/ 0
PERCENTAGE VARIATION PROFILES

  1   0., 8 100., 3  80., 1  40., 1  80., 1 100., 3  10., 4   0., 3   0., 0   0., 0   0., 0   0., 0  PEOPLE  WEEK
  2   0.,24   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0  PEOPLE  WKEND HOL
  3   5., 7  10., 1  20., 1  90., 3  80., 2  90., 3  70., 2  40., 1  40., 1  30., 1   5., 2   0., 0  LIGHT OF WEEK
  4   5.,24   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0   0., 0  LIGHT OF WKEND HOL
DAY NUMBER FOR JANUARY 1 IS  3   LEAP YEAR KEY IS  1
HOL   1/ 1, 1   4/ 4, 0   4/ 6, 1   5/26, 0   8/24, 0   9/ 1, 0  10/13, 0  12/25, 1   0/ 0, 0   0/ 0, 0   0/ 0, 0   0/ 0, 0
DAY TYPE DESCRIPTION AND DISTRIBUTION
 DT  PCT VARIATION PROFILE NUMBERS............ KEY   TIME SCHEDULES  SBT  TST  J F M A M J J A S O N D  S M T W T F S  H
 NO  PEO LTS EOP HSC IRR DPR REA RER REC VOA  OA    OA HS CS SB OR  SCH  SCH

  1    1   3   0   3   0   0   3   0   0   0   0     1  0  1  0  0    0    0   * * * * * * * * * * * *    * * * * *
  2    2   4   0   4   0   0   4   0   0   0   0     2  0  2  0  0    0    0   * * * * * * * * * * * *  *           *   *
SPECIAL HOURLY PRINTOUT
 MO  DAY/DAY   MO  DAY/DAY   MO  DAY/DAY   MO  DAY/DAY   PRINT KEY
  0    0   0    0    0   0    0    0   0    0    0   0       0
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PERCENTAGE VARIATION PROFILES

NUMBER	12 M	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12 N	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
1	0.	0.	0.	0.	0.	0.	0.	0.	100.	100.	100.	80.	40.	80.	100.	100.	100.	10.	10.	10.	10.	0.	0.	0.
3	5.	5.	5.	5.	5.	5.	5.	10.	20.	90.	90.	90.	80.	80.	90.	90.	90.	70.	70.	40.	40.	30.	5.	5.
4	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.

SHUTOFF AND SETBACK TIME SCHEDULE 1

	12 M	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12 N	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
JAN	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
FEB	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
MAR	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
APR	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
JUN	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
JUL	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
AUG	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
SEP	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
OCT	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
NOV	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1

SHUTOFF AND SETBACK TIME SCHEDULE 2

	12 M	1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12 N	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
JAN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FEB	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MAR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
APR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JUN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JUL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AUG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SEP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OCT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NOV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

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ENERGY  REQUIREMENT  ESTIMATE  PROGRAM  FOR

    WEST RUN 7  TR GL 2FG                                         MAR. 29/86

SYSTEM TYPE 8   STD. VARIABLE VOLUME

UNIT VALUES OF INPUT DATA  (FLOOR AREA =    54250. SQFT)

                                LATENT    SENSIBLE
    SOLAR LOAD                              55.69   BTUH/SQFT

    TRANSMISSION LOSS                       0.148   BTUH/F-SQFT
    TRANSMISSION GAIN                       0.150   BTUH/F-SQFT

    TOTAL INTERNAL LOAD          1.18       12.07   BTUH/SQFT
        PEOPLE                   1.10        1.40   BTUH/SQFT
        LIGHTS                              10.23   BTUH/SQFT
        EQUIPMENT                            0.0    BTUH/SQFT
        MISCELLANEOUS            0.08        0.43   BTUH/SQFT

    MINIMUM O/A, COOLING         4.54        1.18   BTUH/SQFT
        OR ...                              0.156   CFM/SQFT
        OR ...                              10.00   PCT OF TOTAL

    PEAK COOLING LOAD            5.60       72.25   BTUH/SQFT
        ROOM SENS ONLY                      67.27   BTUH/SQFT
        TOTAL                                6.49   TONS/1000 SQFT
        OR ...                             154.14   SQFT/TON

    COOLING CAPACITY                        24.00   TONS/1000 SQFT
        OR ...                              41.67   SQFT/TON
        ROOM SENS ONLY                      38.64   BTUH/SQFT

    MINIMUM O/A, HEATING         0.0        15.62   BTUH/SQFT
        OR ...                              0.156   CFM/SQFT
        OR ...                              10.00   PCT OF TOTAL

    PEAK HEATING LOAD            0.0        29.39   BTUH/SQFT

    HEATING CAPACITY                     18433.16   BTUH/SQFT

    TOTAL PROCESS LOAD                       0.0    BTUH/SQFT
        INDIRECT                             0.0    BTUH/SQFT
        DIRECT                               0.0    BTUH/SQFT

    TOTAL BASE ELEC LOAD                     5.66   WATTS/SQFT
        SOURCE A                             3.15   WATTS/SQFT
        SOURCE B                             0.0    WATTS/SQFT
        SOURCE C                             2.51   WATTS/SQFT

    TOT PRIMARY AIRFLOW                     1.555   CFM/SQFT
        OR ...                               64.8   CFM/TON

HEATING     INSIDE = 68. / 0.     OUTSIDE =-25. /  0.
COOLING     INSIDE = 78. / 0.     OUTSIDE = 85. /66.
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ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WEST RUN 7 TR GL 2F8 — MAR. 29/80

MONTHLY AND ANNUAL PEAK LOAD VALUES

	PEAK HEATING, MBH RM LOSS	COILS	PEAK COOLING, TONS RM GAIN	COILS	HUMIDFCN MBH	INDIRECT PROCESS MBH	DIRECT PROCESS MBH	TOT BASE ELECTRIC KW
** JAN **	956.	707.	451.2	0.0	0.	0.	0.	290.
DAY OF MONTH	21	3	30	0	0	0	0	3
TIME OF DAY	5AM	9AM	3PM					3PM
DAY TYPE	1	1	1	0	0	0	0	1
DRY BULB TEMP	-10	-19	41	0	0	0	0	2
DEW POINT TEMP	-14	-21	29	0	0	0	0	-4
** FEB **	1176.	656.	671.3	0.0	0.	0.	0.	290.
DAY OF MONTH	18	28	1	0	0	0	0	1
TIME OF DAY	2AM	4AM	3PM					10AM
DAY TYPE	1	1	1	0	0	0	0	1
DRY BULB TEMP	-6	-13	34	0	0	0	0	21
DEW POINT TEMP	-11	-17	26	0	0	0	0	15
** MAR **	1391.	580.	809.9	0.0	0.	0.	0.	290.
DAY OF MONTH	3	1	12	0	0	0	0	3
TIME OF DAY	6AM	6AM	4PM					11AM
DAY TYPE	1	2	1	0	0	0	0	1
DRY BULB TEMP	-3	-4	32	0	0	0	0	1
DEW POINT TEMP	-6	-6	18	0	0	0	0	-4
** APR **	1518.	488.	830.3	212.7	0.	0.	0.	290.
DAY OF MONTH	7	3	3	28	0	0	0	1
TIME OF DAY	8PM	7AM	4PM	4PM				11AM
DAY TYPE	2	1	1	1	0	0	0	1
DRY BULB TEMP	31	7	22	78	0	0	0	28
DEW POINT TEMP	30	-1	11	29	0	0	0	20
** MAY **	1283.	244.	846.8	197.8	0.	0.	0.	290.
DAY OF MONTH	19	10	16	20	0	0	0	1
TIME OF DAY	3AM	3AM	5PM	4PM				2PM
DAY TYPE	1	2	1	1	0	0	0	1
DRY BULB TEMP	49	36	68	76	0	0	0	54
DEW POINT TEMP	30	30	20	39	0	0	0	42
** JUN **	1271.	193.	779.2	227.8	0.	0.	0.	290.
DAY OF MONTH	23	9	12	3	0	0	0	2
TIME OF DAY	1AM	4AM	5PM	2PM				2PM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	59	42	72	80	0	0	0	73
DEW POINT TEMP	54	48	43	41	0	0	0	48

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WEST RUN 7 TR GL 2P6 MAR. 29/88

MONTHLY AND ANNUAL PEAK LOAD VALUES

	PEAK HEATING, MBH		PEAK COOLING, TONS		HUMIDFCN MBH	INDIRECT PROCESS MBH	DIRECT PROCESS MBH	TOT BASE ELECTRIC KW
	RM LOSS	COILS	RM GAIN	COILS				
** JUL **	1312.	185.	834.9	328.0	0.	0.	0.	290.
DAY OF MONTH	7	1	4	28	0	0	0	1
TIME OF DAY	5AM	4AM	5PM	4PM				10AM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	54	43	86	78	0	0	0	62
DEW POINT TEMP	51	41	47	60	0	0	0	46
** AUG **	1239.	227.	805.7	348.5	0.	0.	0.	290.
DAY OF MONTH	11	27	8	11	0	0	0	1
TIME OF DAY	4AM	5AM	4PM	12 N				2PM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	58	35	74	77	0	0	0	76
DEW POINT TEMP	56	38	51	62	0	0	0	56
** SEP **	1123.	311.	823.1	227.8	0.	0.	0.	290.
DAY OF MONTH	8	13	29	29	0	0	0	2
TIME OF DAY	3AM	6AM	4PM	2PM				11AM
DAY TYPE	1	2	1	1	0	0	0	1
DRY BULB TEMP	41	28	80	80	0	0	0	62
DEW POINT TEMP	37	23	35	41	0	0	0	52
** OCT **	926.	320.	652.4	83.5	0.	0.	0.	290.
DAY OF MONTH	14	27	21	28	0	0	0	1
TIME OF DAY	6AM	2AM	3PM	2PM				2PM
DAY TYPE	1	1	1	1	0	0	0	1
DRY BULB TEMP	30	27	51	61	0	0	0	45
DEW POINT TEMP	30	19	23	32	0	0	0	29
** NOV **	850.	614.	444.3	40.8	0.	0.	0.	290.
DAY OF MONTH	30	26	14	6	0	0	0	3
TIME OF DAY	9PM	6AM	3PM	2PM				2PM
DAY TYPE	2	1	1	1	0	0	0	1
DRY BULB TEMP	11	-8	30	58	0	0	0	35
DEW POINT TEMP	7	-11	23	24	0	0	0	26
** DEC **	1072.	757.	328.8	0.0	0.	0.	0.	290.
DAY OF MONTH	27	27	4	0	0	0	0	1
TIME OF DAY	4PM	10AM	2PM					2PM
DAY TYPE	2	2	1	0	0	0	0	1
DRY BULB TEMP	-19	-26	35	0	0	0	0	29
DEW POINT TEMP	-26	-30	21	0	0	0	0	17
** ANN **	1515.	757.	846.0	348.5	0.	0.	0.	290.
MONTH OF YEAR	4	12	5	8	0	0	0	1
DAY OF MONTH	7	27	16	11	0	0	0	3
TIME OF DAY	8PM	10AM	5PM	12 N				3PM
DAY TYPE	2	2	1	1	0	0	0	1
DRY BULB TEMP	31	-26	68	77	0	0	0	2
DEW POINT TEMP	30	-30	20	62	0	0	0	-4

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WEST RUN 7 TR GL 2F0

MAR. 29/80

MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	357842.	744	0.	0	0.	0.	0.	39601.	0.	51267.	90862.	0
FEB	257827.	672	0.	0	0.	0.	0.	37402.	0.	46799.	84197.	0
MAR	267325.	744	0.	0	0.	0.	0.	39601.	0.	51793.	91398.	0
APR	144929.	703	1320.	20	0.	0.	0.	37813.	0.	49909.	87717.	0
MAY	81954.	680	8883.	147	0.	0.	0.	39601.	0.	50405.	90000.	0
JUN	48344.	555	14618.	184	0.	0.	0.	39395.	0.	48850.	88241.	0
JUL	29395.	436	27863.	226	0.	0.	0.	42766.	0.	54156.	96916.	0
AUG	41456.	531	21765.	199	0.	0.	0.	39601.	0.	51114.	90709.	0
SEP	89978.	637	10158.	119	0.	0.	0.	39395.	0.	51224.	90615.	0
OCT	152657.	744	1328.	38	0.	0.	0.	41183.	0.	52141.	93319.	0
NOV	255112.	720	159.	4	0.	0.	0.	37813.	0.	48616.	86425.	0
DEC	323938.	744	0.	0	0.	0.	0.	39601.	0.	49649.	89245.	0
ANN	2095753.	7910	86095.	937	0.	0.	0.	473769.	0.	605921.	1079634.	0

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WEST RUN. 7 TR GL 2FS — MAR. 29/80

	SO OR SS	MO/DY/TIME	NORM OPER	MO/DY/TIME
MIN ROOM TEMP	68.23 F	1/ 1/12 M	68.23 F	1/ 1/12 M
MAX ROOM TEMP	180.93 F	4/ 8/11AM	180.93 F	4/ 8/11AM
MAX ROOM HUMIDITY RATIO	65.15 GR	1/ 3/ 7AM		

COUNT OF HOURS ON LIMITING CONDITIONS	HEATING	COOLING
SPACE LOAD NOT MET (INCL PICKUP LOAD)	0	1289
SPACE LOAD NOT MET (W/O PICKUP LOAD)	0	1102
SYSTEM CAPACITY EXCEEDED	0	0
LONGEST PICKUP PERIOD	0	7
LAST HOUR OF OCCURRENCE	0/ 0/	2/ 1/ 4PM

UNIT VALUES OF BUILDING ENERGY PEAKS AND CONSUMPTION

ANNUAL EQUIVALENT ENERGY CONSUMPTION = 125598. BTU/SQFT/YR

PEAK HEATING LOAD DURING SETBACK = 0. MBH

HEATING PEAK	13.95	BTUH/SQFT
HEATING CONSUMPTION	38.63	MBTU/SQFT
FULL LOAD HEATING	2768.	HRS
COOLING PEAK	6.42	TONS/1000 SQFT
OR	155.69	SQFT/TON
COOLING CONSUMPTION	1.59	TON-HRS/SQFT
FULL LOAD COOLING	247.	HRS
PROCESS PEAK	0.0	BTUH/SQFT
PROCESS CONSUMPTION	0.0	MBTU/SQFT
INDIRECT	0.0	MBTU/SQFT
DIRECT	0.0	MBTU/SQFT
FULL LOAD PROCESS	0.	HRS
ELECTRIC PEAK	5.35	WATTS/SQFT
ELECTRIC CONSUMPTION	19.90	KWH/SQFT
FULL LOAD ELECTRIC	3723.	HRS

MAX SUPPLY AIRFLOW IS 84388. CFM 1/ 3/ 3PM MIN SUPPLY AIRFLOW IS 33754. CFM 1/ 1/ 1AM

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WEST RUN 7 TR 8L 2FG

MAR. 29/80

YRHR TIME	MO DY	DT CC	DB DP	SORAD RMIS	TRLOAD RMIL	RHSHRC BHSHR1	ZSHG TZSHG	OACFM DELHR	RTEMP RAT	AMAT HRRA	COST HOST	TSA/ZVFC ZVFH	CCLOAD HCLOAD	CLT HLT	D-PROC I-PROC	HUMID RELEC
*** JAN ***																
58	1	1	-19	219593.	-949549.	0.	-208330.	14454.	78.0	50.0	50.0	33754.	0.	0	0.	0.
9AM	3	2	-21	521925.	63579.	0.	543158.	0.0	101.7	17.3	55.0	0.	706533.	0	0.	208.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.
*** FEB ***																
1397	2	1	-13	0.	-932230.	0.	-907465.	0.	78.0	104.7	104.7	33754.	0.	0	0.	0.
4AM	28	0	-17	24765.	208.	0.	-248901.	0.0	104.7	8.3	109.7	0.	656067.	0	0.	63.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.
*** MAR ***																
1423	3	2	-4	0.	-806702.	0.	-781938.	0.	78.0	98.1	98.1	33754.	0.	0	0.	0.
6AM	1	6	-6	24765.	208.	0.	-199074.	0.0	98.1	13.3	103.1	0.	580367.	0	0.	63.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.
*** APR ***																
2216	4	1	7	554577.	-975029.	0.	-370922.	21962.	78.0	50.0	50.0	33754.	0.	0	0.	0.
7AM	3	0	-1	49529.	415.	0.	121917.	0.0	130.1	7.4	55.0	0.	487844.	0	0.	72.
2825	4	1	78	9933346.	-570516.	38796560.	9884761.	84385.	149.4	78.0	50.0	84385.	2851801.	1	0.	0.
4PM	28	1	29	521925.	63579.	34945296.	37042336.	0.0	161.4	24.2	55.0	0.	0.	0	0.	290.
*** MAY ***																
3100	5	2	36	0.	-720353.	0.	-695588.	0.	78.0	127.3	127.3	33754.	0.	0	0.	0.
3AM	10	0	30	24765.	208.	0.	-449168.	0.0	127.3	32.8	132.3	0.	243922.	0	0.	63.
3353	5	1	76	9007812.	-498534.	32808640.	9031203.	84385.	138.5	78.0	50.0	84385.	2369529.	1	0.	0.
4PM	28	4	39	521925.	63579.	29900192.	31997232.	0.0	150.5	36.0	55.0	0.	0.	0	0.	290.
*** JUN ***																
3821	6	1	42	0.	-928506.	0.	-903741.	0.	78.0	159.2	159.2	33754.	0.	0	0.	0.
4AM	9	1	40	24765.	208.	0.	-707788.	0.0	159.2	47.6	164.2	0.	193455.	0	0.	63.
3687	6	1	80	5614565.	-470870.	33112368.	5665619.	84385.	136.2	80.0	50.0	84385.	2734073.	1	0.	0.
2PM	3	3	41	521925.	63579.	26747232.	28844272.	0.0	151.0	39.2	55.0	0.	0.	0	0.	290.

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

WEST RUN 7 TR GL 2FG

MAR. 29/80

YRHR TIME	MO DY	DT CC	DB DP	SORAD RMIS	TRLOAD RMIL	BHSHRC BHSHRI	ZSHG TZSHG	OACFM DELHR	RTEMP RAT	AWAT HRRA	CDST HDST	TSA/ZVPC ZVFH	CCLOAD HCLOAD	CLT HLT	D-PROC I-PROC	HUMID RELEC
*** JUL ***																
4349	7	1	43	0.	-1003063.	0.	-978298.	0.	78.0	169.5	169.5	33754.	0.	0	0.	0.
4AM	1	0	41	24765.	208.	0.	-790756.	0.0	169.5	50.7	174.5	0.	185044.	0	0.	63.
5009	7	1	78	9007812.	-586980.	39916768.	8942756.	84385.	150.5	78.0	50.0	84385.	3936486.	1	0.	0.
4PM	28	4	60	521925.	63579.	34787440.	36884480.	23.71	163.5	84.9	55.0	0.	0.	0	0.	290.
*** AUG ***																
5718	8	1	38	0.	-694721.	0.	-669956.	0.	78.0	126.1	126.1	33754.	0.	0	0.	0.
5AM	27	8	38	24765.	208.	0.	-440359.	0.0	126.1	43.9	131.1	0.	227100.	0	0.	63.
5341	8	1	77	3014599.	-828600.	55803648.	2612696.	84385.	172.0	77.0	50.0	84385.	4181474.	1	0.	0.
12 N	11	2	62	426700.	27260.	39578192.	41675232.	29.47	192.5	54.2	55.0	0.	0.	0	0.	273.
*** SEP ***																
6127	9	2	28	0.	-615888.	0.	-591123.	0.	78.0	106.3	106.3	33754.	0.	0	0.	0.
6AM	13	1	23	24765.	208.	0.	-277415.	0.0	106.3	19.4	111.3	0.	311211.	0	0.	63.
6519	9	1	80	6573674.	-519267.	36404000.	6576331.	84385.	142.5	80.0	50.0	84385.	2734073.	1	0.	0.
2PM	29	0	41	521925.	63579.	29962064.	32059104.	0.0	157.1	39.2	55.0	0.	0.	0	0.	290.
*** OCT ***																
7179	10	1	27	0.	-916980.	0.	-892215.	0.	78.0	142.8	142.8	33754.	0.	0	0.	0.
2AM	27	0	19	24765.	208.	0.	-570096.	0.0	142.8	35.6	147.8	0.	319622.	0	0.	63.
7215	10	1	61	5477742.	-327949.	13012280.	5671717.	84385.	102.3	61.0	50.0	84385.	1002494.	1	0.	0.
2PM	28	4	32	521925.	63579.	12716923.	14813956.	0.0	114.3	27.5	55.0	0.	33644.	0	0.	290.
*** NOV ***																
7903	11	1	-8	0.	-817530.	0.	-792866.	0.	78.0	95.4	95.4	33754.	0.	0	0.	0.
6AM	25	6	-11	24765.	208.	0.	-176357.	0.0	95.4	10.0	100.4	0.	614011.	0	0.	63.
7431	11	1	58	4399047.	-216139.	3768861.	4704832.	84385.	85.9	58.0	50.0	84385.	729086.	1	0.	0.
2PM	6	3	24	521925.	63579.	5304878.	7401911.	0.0	97.3	19.9	55.0	0.	58878.	0	0.	290.
*** DEC ***																
8651	12	2	-26	820097.	-1089946.	0.	-245084.	0.	78.0	111.3	111.3	33754.	0.	0	0.	0.
10AM	27	5	-30	24765.	208.	0.	514413.	0.0	111.3	10.8	116.3	0.	757000.	0	0.	63.
0	0	0	0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	0.	0	0.	0.
0	0	0	0	0.	0.	0.	0.	0.0	0.0	0.0	0.0	0.	0.	0	0.	0.

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APPENDIX A-2

GLOSSARY OF TERMS USED IN ENERGY REQUIREMENT ESTIMATE (ERE)

APPENDIX A-2

GLOSSARY OF TERMS USED IN ENERGY REQUIREMENT ESTIMATE (ERE)

Term	Location on Input Sheets: Card	Cols.	Remarks
AR KY	5A	73	Key for air handling unit fan operation during setback.
BEA	10	15 - 15	Percentage variation profile number for the source A base electric load.
BEB	10	16 - 17	Percentage variation profile number for the source B base electric load.
BEC	10	18 - 19	Percentage variation profile number for the source C base electric load.
CDDB	4	38 - 40	Ambient dry bulb on the cooling cycle, F.
CDDP	4	41 - 43	Ambient design dew point on the cooling cycle, F.

CDST	4	51 - 53	Cold deck supply temperature or primary cold coil leaving temperature, F.
CDTG	4	44 - 50	Cooling design transmission gain, MBh.
CDTL	5	65 - 67	Cold air supply temperature at the lower ambient limit, F.
CDTU	5	59 - 61	Cold air supply temperature at the upper ambient limit, F.
CDTUO	5	68 - 70	cold air supply temperature to be in effect during unoccupied periods (determined by outside air shutoff schedule), F
CIDB	4	32 - 34	Indoor design dry bulb on the cooling cycle, F
CIDP	4	35 - 37	Indoor design dew point on the cooling cycle, F.
CS	10	22	Number of the shutoff schedule to be used for this day type for the cooling system.

CSCAP	3	41 - 45	cooling system capacity, tons.
DPR	10	12 - 13	Percentage variation profile number for the direct process load.
DR	6		Duration of a shutoff period in hours.
EFFL	5	77 - 80	Latent efficiency of outside air/exhaust air heat recovery system.
EFFS	5	73 - 76	Sensible efficiency of outside air/exhaust air heat recovery system.
EL KY	5-A	39	Key for the supplemental heating to be converted to electricity on the ERE output tape.
EQP	10	6 - 7	Percentage variation profile number for the internal load from equipment.
FLOOR	2	9 - 15	Air conditioned floor area, sq.ft.
HDDB	4	7 - 9	Ambient design dry bulb on the heating cycle, F.

HDDP	4	10 - 12	ambient design dew point on the heating cycle, F.
HDSTL	4	29 - 31	Hot deck suply temperature at the lower ambient limit, F.
HDSTU	4	23 - 25	Hot deok supply temperature at the upper ambient limit, F.
HDTL	4	13 - 19	Heating design transmission loss, MBH
HI AM	5-A	68 - 69	Ambient temperature for highest room dp
HI DP	5-A	66 - 67	Highest room dew point in humidifcation reset schedule.
HIDB	4	1 - 3	Indoor design dry bulb on the heating cycle , F.
HIDP	4	4 - 6	Indoor design dew point on the heating cycle, F.
HM KY	5-A	72	Sprayed coil humidification key.
HR	6		Beginning hour number of a shutoff period.

HRCD	4	54 - 56	Humidity ratio of the cold deck or primary cold coil, grains/lb,
HRS	3	55 - 56	Number of hours of interruption duration.
HS	10	21	Number of the shutoff schedule to be used for this day type for the heating system.
HSCAP	3	35 - 40	Heating capacity, MBH.
HSF	4	76 - 80	Heat storage factor, BTu/F-sq.ft.
IN KY	5-A	80	Infiltration key
INTCST	3	49 - 51	Cooling system shutoff temperature, F.
INTHST	3	46 - 48	Heating system shutoff temperature, F.
IPR	10	10 - 11	Percentage variation profile number for the indirect process load.
KEYOA	10	73	Outside air key
KHSF	4	80	Key for duration of pickup of heat storage.

LO AM	5-A	70 - 71	Lowest ambient temperature for humidification.
LTS	10	4 - 5	Percentage variation profile number for the internal load from lights.
MO/MO	6		Month numbers beginning with and thru which preceding shutoff schedule shall apply.
MSC	10	8 - 9	Percentage variation profile number for the internal load from any miscellaneous source.
OA	10	20	Number of the shutoff schedule to be used for this day type for outside air.
OAMINC	5	29 - 35	Minimum outside airflow on the cooling, cfm.
OAMINH	5	36 - 42	Minimum outside airflow on the heating cycle, cfm.
OAMINS	5	43 - 49	Minimum outside airflow during "shutoff" period, cfm.

OAVMAX	5	22 - 28	Maximum outside airflow, cfm.
OP	10	45	Time schedule number for off-peak electrical usage.
PBEA	2	66 - 70	Peak base electric load for source A, kw
PBEB	2	71 - 75	Peak base electric load for source B, kw
PBEC	2	76 - 79	Peak base electric load for source C, kw
PCILTR	2	35 - 37	Percent of lighting load which passes directly into the return air stream.
PCIML	2	51 - 53	Percent of miscellaneous internal load which is latent.
PCIPL	2	27 - 29	Percent of internal load from people which latent.
PCLTRH	2	38 - 40	A percent of the percent of the lighting load which passes directly into the return air stream which is available for reheat.
PFIT	3	52 - 54	Primary fuel interruption temperature, F.

PIE	2	41 - 45	Peak internal load from equipment MBh
PILT	2	30 - 34	Peak internal load from lights, MBh
PIM	2	46 - 50	Peak internal load from any miscellaneous source, MBh
PIP	2	22 - 26	Peak internal load from people, MBh
PPD	2	60 - 65	Peak direct-fired process load, MBh
PPI__	2	54 - 59	Peak indirect process load, MBh
PR KY	5-A	65	Process key indicating which process load is to be reduced by preceding percentages.
RASOLM	4	66 - 69	Return air solar gain at summer design, MBh
RATRLM	4	73 - 75	Return fan delta T or temperature rise, F
SB	10	23	Number of the setback time schedule to be used for this day type.
SBT SCH	10	24	Number of the setback temperature schedule to be used for this day type.

SCDST	4	57 - 59	Secondary cold deck supply temperature, F.
SFDT	4	70 - 72	Supply fan delta T or temperature rise, F.
SHRCD	4	60 - 61	Humidity ratio of the secondary cold coil, grains/lb.
SOLAR	2	16 - 21	Reference solar load, MBh
SY KY	5-A	40	Supplemental system operation key
SYS TP	2	6	System Type.
TLCDL	5	62 - 64	Lower ambient temperature limit for cold supply air temperature schedule, F.
TLCDU	5	58 - 58	Upper ambient temperature limit for cold supply air temperature schedule, F.
TLEL	5	53 - 55	Lower temperature limit for the economizer cycle, F.
TLEU	5	50 - 52	Upper temperature limit for the economizer cycle, F.

TLHDL	4	26 - 28	Lower ambient temperature limit for hot deck temperature schedule, F.
TLHDU	4	20 - 22	upper ambient temperature limit for hot deck temperature schedule, F.
TSA	5	1 - 7	total supply airflow, cfm
VOA	10	71 - 72	Profile number for variable outside air schedule.
VVMAF	5	71 - 72	Minimum percentage of supply airflow for variable volume systems.
ZVFCM	5	8 - 14	Maximum cold deck airflow, cfm
ZVFHM	5	15 - 21	Maximum hot deck airflow, cfm.